TOTAL MAXIMUM DAILY LOAD FOR METALS
LOS ANGELES RIVER AND TRIBUTARIES

U.S. Environmental Protection Agency

Region 9

California Regional Water Quality Control Board

Los Angeles Region

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ACF	Acute Conversion Factor
BLM	Biotic Ligand Model
BMPs	Best Management Practices
Caltrans	California Department of Transportation
CCF	Chronic Conversion Factor
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CTR	California Toxics Rule
CWA	Clean Water Act
EFDC1D	Environmental Fluid Dynamics Code 1-D
EMC	Event Mean Concentration
FHWA	Federal Highway Administration
GWR	Ground Water Recharge
HSPF	Hydrologic Simulation Program-Fortran
IPWP	Integrated Plan for the Wastewater Program
IRP	Integrated Resources Plan
LACDPW	Los Angeles County Department of Public Works
LARWQCB	Los Angeles Regional Water Quality Control Board
LSPC	Loading Simulation Program in C++-
MCLs	Maximum Contaminant Levels
MGD	Million Gallons Per Day
MS4	Municipal Separate Storm Sewer System
MUN	Municipal Supply
NCDC	National Climatic Data Center
NHD	National Hydrography Dataset
NPDES	National Pollutant Discharge Elimination System
POTW	Publicly Owned Wastewater Treatment Works
SCAG	Southern California Association of Governments

SCCWRP	Southern California Coastal Water Research Project
SIP	State Implementation Plan
TMDL	Total Maximum Daily Loads
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VOCs	Volatile Organic Compounds
WASP5	Water Quality Analysis Simulation Program
WDRs	Waste Discharge Requirements
WER	Water Effect Ratio
WLA	Waste Load Allocation
WMP	Watershed Monitoring Program
WQBELs	Water Quality Based Effluent Limits
WQOs	Water Quality Objectives
WRPs	Water Reclamation Plants

1. INTRODUCTION

Segments of the Los Angeles River and its tributaries exceed water quality objectives for a variety of metals. These segments (*i.e.,* reaches) of the Los Angeles River and tributaries are included on the California 303(d) list of impaired waterbodies (LARWQCB, 1998a and 2002). The Clean Water Act requires a Total Maximum Daily Load (TMDL) be developed to restore the impaired waterbodies, including the Los Angeles River, to its full beneficial uses. Table 1 summarizes the stream reaches of the Los Angeles River watershed included on the California 303(d) list for metals.

Table 1. Segments of the Los Angeles River and tributaries listed as impaired for metals (LARWQCB, 1998a and 2002)

Listed Waterbody Segment	Copper	Cadmium	Lead	Zinc	Aluminum	Selenium
Aliso Canyon Creek						X
Dry Canyon Creek						N
McCoy Canyon Creek						N
Monrovia Canyon Creek			X			
Los Angeles River Reach 4 (Sepulveda Dam to Riverside St.)			X			
Tujunga Wash (from Hansen Dam to Los Angeles River)	X					
Burbank Western Channel		X				
Los Angeles River Reach 2 (from Figueroa St. to Carson St.)			X			
Rio Hondo (from the Santa Ana Fwy to Los Angeles River)	X		X	X		
Compton Creek	X		X			
Los Angeles River Reach 1 (from Carson St. to estuary)	N	N	X	N	N	

X: listed as impaired in 1998 303(d) list and part of analytical unit 13. N: New waterbody listing based on 2002 303(d) list, not part of analytical unit 13

The goal of this TMDL is to develop pollutant allocations for metals and an implementation plan to meet the water quality objectives in the Los Angeles River and listed tributaries. This TMDL complies with 40 CFR 130.2 and 130.7, Section 303(d) of the Clean Water Act and U.S.

Environmental Protection Agency (EPA) guidance for developing TMDLs in California (USEPA, 2000a). This document summarizes the information used by the EPA and the California Regional Water Quality Control Board, Los Angeles Region (Regional Board) to develop allocations for metals. The TMDL also includes an implementation plan and cost estimate to achieve the allocations and attain water quality objectives (WQOs) in the Los Angeles River. The California Water Code (Porter-Cologne Water Quality Control Act) requires that an implementation plan be developed to achieve water quality objectives. Figure 1 shows the waterbodies addressed in this TMDL.

1.1 Regulatory Background

Section 303(d) of the Clean Water Act (CWA) requires that each State "shall identify those waters within its boundaries for which the effluent limitations are not stringent enough to implement any water quality objective applicable to such waters." The CWA also requires states to establish a priority ranking for waters on the 303(d) list of impaired waters and to establish TMDLs for such waters.

The elements of a TMDL are described in 40 CFR 130.2 and 130.7 and Section 303(d) of the CWA, as well as in the U.S. Environmental Protection Agency guidance (USEPA, 2000a). A TMDL is defined as the "sum of the individual waste load allocations for point sources and load allocations for nonpoint sources and natural background" (40 CFR 130.2) such that the capacity of the waterbody to assimilate pollutant loads (the loading capacity) is not exceeded. A TMDL is also required to account for seasonal variations and include a margin of safety to address uncertainty in the analysis (USEPA, 2000).

States must develop water quality management plans to implement the TMDL (40 CFR 130.6). The EPA has oversight authority for the 303(d) program and is required to review and either approve or disapprove the TMDLs submitted by states. In California, the State Water Resources Control Board (State Board) and the nine Regional Water Quality Control Boards are responsible for preparing lists of impaired waterbodies under the 303(d) program and for preparing TMDLs, both subject to EPA approval. If EPA disapproves a TMDL submitted by a state, EPA is required to establish a TMDL for that waterbody. The Regional Boards also hold regulatory authority for many of the instruments used to implement the TMDLs, such as the National Pollutant Discharge Elimination System (NPDES) permits and state-specified Waste Discharge Requirements (WDRs).

The Regional Board identified over 700 waterbody-pollutant combinations in the Los Angeles Region requiring TMDLs (LARWCQB, 1996, 1998a). These are referred to as "listed" or "303(d) listed" waterbodies or waterbody segments. A schedule for development of TMDLs in the Los Angeles Region was established in a consent decree (Consent Decree) approved on March 22, 1999 (Heal the Bay Inc., et al. v. Browner, C 98-4825 SBA). For the purpose of scheduling TMDL development, the decree combined the more than 700 waterbody-pollutant combinations into 92 TMDL analytical units. The 303(d) list was updated in 2002. These updates and changes are not reflected in the Consent Decree.

This TMDL addresses Analytical Unit #13 of the Consent Decree which consists of segments of the Los Angeles River and tributaries with impairments by metals (cadmium, copper, lead, selenium, and zinc). Table 1 identifies the listed waterbodies by the metals causing impairments. The Consent Decree schedule requires that this TMDL be completed by March 22, 2004. If the Regional Board fails to develop the TMDL, EPA must promulgate the TMDL by March 22, 2005. It is the Regional Board's intent to complete this TMDL prior to EPA promulgation. The 2002 303(d) listings approved in 2003 are not required to be addressed per the Consent Decree; however where appropriate, this TMDL addressed those listings as well.

This report presents the TMDL for metals and summarizes the analyses performed by EPA and the Regional Board to develop this TMDL. This report does not address the metals TMDLs required for four lakes in the Los Angeles River watershed as part of Analytical Unit #20. These four lakes (Lake Calabasas, Echo Lake, Lincoln Park Lake and Peck Road Lake) are not hydrologically connected to the Los Angeles River or the listed tributaries. The TMDLs for these lakes are not scheduled in the Consent Decree but must be established by March 22, 2012. This report does not address metals impairments for Los Angeles Harbor or San Pedro Bay required under Analytical Units #75 and #78, respectively. These TMDLs have not been scheduled in the Consent Decree.

1.2 Environmental Setting

The Los Angeles River flows for 55 miles from the Santa Monica Mountains at the western end of the San Fernando Valley to Queensway Bay located between the Port of Long Beach and the City of Long Beach. It drains a watershed with an area of 834 square miles. Approximately 44% of the watershed area can be classified as forest or open space. These areas are primarily within the headwaters of the Los Angeles River in the Santa Monica, Santa Susana, and San Gabriel Mountains, including the Angeles National Forest, which comprises 250 square miles of the watershed. Approximately 36% of the land use can be categorized as residential, 10% as industrial, 8% as commercial, and 3% as agriculture, water and other. The more urban uses are found in the lower portions of the watershed.

The natural hydrology of the Los Angeles River Watershed has been altered by channelization and the construction of dams and flood control reservoirs. The Los Angeles River and many of its tributaries are lined with concrete for most or all of their lengths. Soft-bottomed segments of the Los Angeles River occur where groundwater upwelling prevented armoring of the river bottom. These areas typically support riparian habitat.

The mainstem of the Los Angeles River begins by definition at the confluence of Arroyo Calabasas (which drains the northeastern portion of the Santa Monica Mountains) and Bell Creek (which drains the Simi Hills). McCoy Canyon Creek and Dry Canyon Creek (listed for selenium) are tributary to Arroyo Calabasas. The river flows east from its origin along the southern edge of the San Fernando Valley. The Los Angeles River also receives flow from Browns Canyon, Aliso Creek (listed for selenium) and Bull Creek which drain the Santa Susana Mountains. The lower portions of Arroyo Calabasas and Bell Creek are channelized. Browns Canyon, Aliso Creek and Bull Creek are completely channelized.

Reach 5 of the Los Angeles River runs through Sepulveda Basin. The Sepulveda Basin is a 2,150-acre open space designed to collect floodwaters during major storms. Because the area is periodically inundated, it remains in natural or semi-natural conditions and supports a variety of low-intensity land uses. The D.C. Tillman Wastewater Reclamation Plant, a publicly owned wastewater treatment works (POTW) operated by the City of Los Angeles, discharges directly to the Los Angeles River just below the dam and also via two lakes in the Sepulveda Basin that are used for recreational and wildlife habitat. The POTW has a treatment design capacity of 80 million gallons per day (mgd) and contributes a substantial flow to the Los Angeles River. There are no listings for metals in Reach 5 of the Los Angeles River.

Reach 4 of the Los Angeles River runs from Sepulveda Dam to Riverside Street. This section of the river is listed for lead. Pacoima Wash and Tujunga Wash are the two main tributaries to this reach. Both tributaries drain portions of the Angeles National Forest in the San Gabriel Mountains. Pacoima Wash is channelized below Lopez Dam to the Los Angeles River. Tujunga Wash (listed for copper) is channelized for the 10-mile reach below Hansen Dam. Some of the discharge from Hansen Dam is diverted to spreading grounds for groundwater recharge, but most of the flow enters the channelized portion of the stream.

Reach 3 of the Los Angeles River, which runs from Riverside Street to Figueroa Street, is not listed for metals. The two major tributaries to this reach are the Burbank Western Channel and Verdugo which drain the Verdugo Mountains. Both tributaries are channelized. The Western Channel receives flow from the Burbank Water Reclamation Plant, a POTW with a design capacity of 9 mgd. Burbank Western Channel is listed for cadmium.

At the eastern end of the San Fernando Valley, the Los Angeles River turns south around the Hollywood Hills and flows through Griffith Park and Elysian Park in an area known as the Glendale Narrows. This area is fed by natural springs during periods of high groundwater. The river is channelized and the sides are lined with concrete. The river bottom in this area is unlined because the water table is high and groundwater routinely discharges into the channel, in varying volumes depending on the height of the water table. The Los Angeles-Glendale Water

Reclamation Plant, operated by the City of Los Angeles, has a design capacity of 20 mgd and discharges to the Los Angeles River in the Glendale Narrows.

Reach 2 of the Los Angeles River, which runs from Figueroa Street to Carson Street, is listed for lead. The first major tributary below the Glendale Narrows is the Arroyo Seco, which drains areas of Pasadena and portions of the Angeles National Forest in the San Gabriel Mountains. In wet periods, rising stream flows in the Los Angeles River above Arroyo Seco have been related to the increase of rising groundwater. There is up to 3,000 acre-feet of recharge from the Pollock Well Field area that adds to the rising groundwater. For the 2000-01 water year, the total rising groundwater flow was estimated at 3,900 acre-feet (ULARA Watermaster Report, 2000-2001 Water Year, May 2002).

The next major tributary is the Rio Hondo. The Rio Hondo and its tributaries drain a large area in the western portion of the watershed. Flow in the Rio Hondo is managed by the Los Angeles County Department of Public Works (LACDPW). At Whittier Narrows, flow from the Rio Hondo can be diverted to the Rio Hondo Spreading Grounds. During dry weather, virtually all the water in the Rio Hondo goes to groundwater recharge, so little or no flow exits the spreading grounds to Reach 1 of the Rio Hondo. During storm events, Rio Hondo flow that is not used for spreading, reaches the Los Angeles River. This flow is comprised of both stormwater and treated wastewater effluent from the Whittier Narrows Water Reclamation Plant. Reach 1 of the Rio Hondo is listed for copper, lead, and zinc. Monrovia Canyon Creek is also listed for lead. This creek, located in the foothills of the San Gabriel Mountains in the National Forest, is a tributary to Sawpit Creek which runs into Peck Lake and ultimately to Rio Hondo Reach 2 above the spreading grounds.

Reach 1 of the Los Angeles River, which runs from Carson Street to the estuary, was listed for lead in 1998. Listings for aluminum, copper, cadmium, and zinc were added in 2002 based on exceedances of standards in stormwater samples. Compton Creek (listed for copper and cadmium) is the last large tributary to the system before the river enters the estuary. The creek is channelized for most of its 8.5 mile length. It receives up to 720 mgd of hydrotest and stormwater from Southern California Edison Company on an intermittent basis.

The tidal portion of the Los Angeles River begins at Willow Street and runs approximately three miles before joining with Queensway Bay located between the Port of Long Beach and the City of Long Beach. In this reach, the channel has a soft bottom with concrete-lined sides. Sandbars accumulate in the portion of the river where tidal influence is limited.

During dry weather, most of the flow in the Los Angeles River is comprised of wastewater effluent from the Tillman, Los Angeles-Glendale and Burbank treatment plants. In the dry season, POTW mean monthly discharges totaled 70% to 100% of the monthly average flow in the river. The median flow in the Los Angeles River, measured at the LACDPW Wardlow station, was 94 mgd (145 cfs) over a 12-year period (October 1998 through December 2000). During wet weather, the river's flow may increase by two to three orders of magnitude due to stormwater runoff. Based on measurements at Wardlow (October 1988 through December 2000) flows greater than 322 mgd (501 cfs) were observed 10% of the time. In months with rain events, POTW monthly average discharges together were less than 20% of the monthly average flow in the river.

The high flows in the wet season originate as storm runoff both from the areas of undeveloped open space in the mountains of the tributaries' headwaters and from the urban land uses in the flat low-lying areas of the watershed. Rainfall in the headwaters flows rapidly because the watershed and stream channels for the most part are steep. In the urban areas, about 5,000 miles of storm drains in the watershed convey stormwater flows and urban runoff to the Los Angeles River. The watershed produces storm flow in the river with a sharply peaked hydrograph where flow increases quite rapidly after the beginning of rain events in the watershed, and declines rapidly after rainfall ceases. The Los Angeles River metals TMDL therefore should account for differences in both flow and the relative contributions of pollutant sources between wet and dry periods.

1.3. Elements of a TMDL

Guidance from USEPA (1991) identifies seven elements of a TMDL. Sections 2 through 8 of this document are organized such that each section describes one of the elements, with the analysis and findings of this TMDL for that element. The elements are:

- Section 2: Problem Identification. This section reviews the metals data used to add the waterbody to the 303(d) list, and summarizes existing conditions using that evidence along with any new information acquired since the listing. This element identifies those reaches that fail to support all designated beneficial uses; the beneficial uses that are not supported for each reach; the water quality objectives (WQOs) designed to protect those beneficial uses; and, in summary, the evidence supporting the decision to list each reach, such as the number and severity of exceedances observed.

- Section 3: Numeric Targets. For this TMDL, the numeric targets are based upon the WQOs described in the California Toxics Rule (CTR).

- Section 4: Source Assessment. This section develops the estimate of metals loadings from point sources and non-point sources into the Los Angeles River.

- Section 5: Linkage Analysis. This analysis shows how the sources of metals compounds into the waterbody are linked to the observed conditions in the impaired waterbody. The linkage analysis addresses the critical conditions of stream flow, loading, and water quality parameters.

- Section 6: Pollutant Allocation. Each pollutant source is allocated a quantitative load of metals that it can discharge to meet the numeric targets. Allocations are designed such that the waterbody will not exceed numeric targets for any of the compounds or related effects. Allocations are based on critical conditions, so that the allocated pollutant loads may be expected to remove the impairments at all times.

- Section 7: Implementation. This section describes the plans, regulatory tools, or other mechanisms by which the waste load allocations and load allocations are to be achieved. This section contains a cost analysis. The TMDL provides cost estimates to implement waste load allocations assigned to NPDES dischargers including the major Publicly Owned Treatment Works (POTWs) and stormwater permittees.

- Section 8: Monitoring. This TMDL includes a requirement for monitoring the waterbody to ensure that the water quality standards are attained. If the monitoring results demonstrate the TMDL has not succeeded in removing the impairments, then revised allocations will be developed. It also describes special studies to address uncertainties in assumptions made in the development of this TMDL and the process by which new information may be used to refine the TMDL.

2. PROBLEM IDENTIFICATION

This section provides an overview of water quality standards for the Los Angeles River and reviews water quality data used in the 1998 water quality assessment, the 2002 303(d) listing and any additional data which may be pertinent to the assessment of condition.

2.1 Water Quality Standards

California state water quality standards consist of the following elements: 1) beneficial uses; 2) narrative and/or numeric water quality objectives; and 3) an antidegradation policy. In California, beneficial uses are defined by the Regional Water Quality Control Boards (Regional Boards) in the Water Quality Control Plans (Basin Plans). Numeric and narrative objectives are specified in each region's Basin Plan. These are designed to be protective of the beneficial uses in each waterbody in the region or State Water Quality Control Plans. Numeric objectives for toxics can be found in the California Toxics Rule (40 CFR 131.38).

2.1.1. Beneficial Uses. The Basin Plan for the Los Angeles Regional (1994) defines 13 beneficial uses for the Los Angeles River. These uses are summarized in Table 2. The Basin

Plan (1994) identifies beneficial uses as existing (E), potential (P), or intermittent (I) uses. Although all beneficial uses must be protected, we focus our discussion on those uses that are most likely to be impacted by metals loadings to the Los Angeles River. These are the beneficial uses associated with aquatic life (i.e., wildlife habitat, warm freshwater water habitat, rare threatened or endangered species, wetland habitat, and marine habitat) and water supply (i.e., groundwater recharge).

Existing use designations for warm freshwater, wildlife, wetland, and rare, threatened or endangered species habitats (WARM, WILD, WET, and RARE) apply over much of the mainstem and Compton Creek in the lower part of the watershed. The WARM designation applies as either an intermittent or potential use to the remaining listed tributaries. The WILD designation is for the protection of fish and wildlife. This use applies to much of the mainstem of the Los Angeles River, as an intermittent use in Rio Hondo, and as potential use in the remainder of the tributaries. Water quality objectives developed for the protection of fish and wildlife are applicable to the reaches with the WARM, WILD, WET and RARE designations.

Table 2. Beneficial uses in listed reaches of the Los Angeles River (LARWQCB, 1994)

STREAM REACH	MUN	GWR	REC1	REC2	WILD	WARM	SHELL	RARE	MIGR	SPWN	WET	MAR	IND	PROC
Los Angeles River to Estuary	P*	E	E[1]	E	E	E	P[1]	E	P	P		E	P	P
Los Angeles River (Hydro. Unit 405.12)	P*	E	E[1]	E	P	E							P	
Los Angeles River (Hydro. Unit 405.15)	P*	E	E	E	E	E					E		P	
Compton Creek	P*	E	E[1]	E	E	E					E			
Rio Hondo Spreading Grounds and below	P*	I	P[1]	E	I	P								
Rio Hondo to Spreading Grounds	P*	I	I[1]	E	I	P		E			E			
Monrovia Canyon Creek	I	I	I	I	E	I					E			
Burbank Western Channel	P*		P[1]	I	P	P								
Tujunga Wash	P*	I	P[1]	I	P	P								
Aliso Creek	P*	I	I[1]	I	E	I								
McCoy Canyon Creek	P*	I	I	I	E	I								
Dry Canyon Creek	P*	I	I[1]	I	E	I								

*Municipal designations marked with an asterisk are conditional.

E: Existing beneficial use, P: Potential beneficial use, I: Intermittent beneficial use, 1: Use restricted by LACDPW

The municipal supply (MUN) use designation applies to several tributaries to the Los Angeles River and all groundwater in the Los Angeles River watershed. Other waterbodies within Region 4 also have a conditional designation for MUN. These waterbodies are indicated with an asterisk in the Basin Plan. However, conditional designations are not recognized under federal law and are not water quality standards requiring TMDL development at this time. (See Letter from Alexis Strauss [USEPA] to Celeste Cantú [State Board], Feb. 15, 2002.) The ground water recharge (GWR) use designation applies to the Los Angeles River and its tributaries as either an existing or intermittent beneficial use.

2.1.2 Water Quality Objectives (WQOs). Narrative water quality objectives are specified by the 1994 Regional Board Basin Plan. The following two narrative standards are most pertinent to the metals TMDL:

> *Surface waters shall not contain concentrations of chemical constituents in amounts that adversely affect any designated beneficial use.*

> *Toxic substances shall not be present at levels that will bioaccumulate in aquatic life resources to levels which are harmful to aquatic life or human health.*

Numeric water quality objectives for several pollutants addressed in this TMDL were promulgated by EPA in 2000 in the California Toxics Rule (CTR). The listed pollutants covered by CTR objectives include selenium, cadmium, copper, lead, and zinc (Table 3). The selenium and cadmium objectives were established contingent on an EPA commitment to revise the objectives to better protect wildlife.

The freshwater CTR values for cadmium, copper, lead, and zinc are based on the dissolved fraction and are hardness dependent (USEPA 2000a). The freshwater CTR standard for selenium is based on the total fraction. However, EPA acknowledged in its consultations with the U.S. Fish and Wildlife Service (USFWS) that the freshwater standards for selenium may not be fully protective of wildlife, and EPA committed to revisit and, if necessary, revise the selenium criteria in the near future.

CTR freshwater aquatic life criteria for certain metals are expressed as a function of hardness because hardness and/or water quality characteristics that are usually correlated with hardness can reduce or increase the toxicity of some metals. Hardness is used as a surrogate for a number of water quality characteristics, which affect the toxicity of metals in a variety of ways. Increasing hardness has the effect of decreasing the toxicity of metals. Water quality criteria to protect aquatic life may be calculated at different concentrations of hardness measured in milligrams per liter (mg/L) as calcium carbonate ($CaCO_3$). The CTR lists freshwater aquatic life criteria based on a hardness value of 100 mg/L and provides hardness dependent equations to calculate the freshwater aquatic life metals criteria using site-specific hardness data.

Table 3. Water quality objectives established in CTR. Values in table are based on a hardness value of 100 mg/L as calcium carbonate. Metals values reported as µg/L.

Metal	Freshwater Chronic	Freshwater Acute
Cadmium (dissolved)	2.2	4.3
Copper (dissolved)	9	13
Lead (dissolved)	2.5	65
Selenium (total)	5	Reserved
Zinc (dissolved)	120	120

The formula for calculating the acute and chronic objectives for cadmium, copper, lead, and zinc in the CTR take the form of the following equation:

$$CMC = WER * ACF * EXP[(m_a)(\ln(hardness)+b_a]$$

$$CCC = WER * CCF * EXP[(m_c)(\ln(hardness)+b_c]$$

Where:

WER = Water Effects Ratio (assumed to be 1)

ACF = Acute conversion factor (to convert from the total to the dissolved fraction)

CCF = Chronic conversion factor (to convert from the total to the dissolved fraction)

m_A = slope factor for acute criteria

m_C = slope factor for chronic criteria

b_A = y intercept for acute criteria

b_C = y intercept for chronic criteria

The CTR allows for the adjustment of criteria through the use of a water-effect ratio (WER) to assure that the metals criteria are appropriate for the site-specific chemical conditions under which they are applied. A WER represents the correlation between metals that are measured and metals that are biologically available and toxic. A WER is a measure of the toxicity of a material in site water divided by the toxicity of the same material in laboratory dilution water. No site-specific WER has been developed for the Los Angeles River. Therefore, a WER default value of 1.0 is assumed.

The coefficients needed for the calculation of objectives are provided in the CTR for most metals (Table 4). The conversion factors for cadmium and lead are hardness-dependent. The following equations can be used to calculate the conversion factors based on site-specific hardness data:

$$\text{Cadmium ACF} = 1.136672 - [(\ln\{\text{hardness}\})(0.041838)]$$
$$\text{Cadmium CCF} = 1.101672 - [(\ln\{\text{hardness}\})(0.041838)]$$
$$\text{Lead ACF} = 1.46203 - [(\ln\{\text{hardness}\})(0.145712)]$$
$$\text{Lead CCF} = 1.46203 - [(\ln\{\text{hardness}\})(0.145712)]$$

Table 4. Coefficients used in formulas for calculating CTR standards

Metal	ACF	m_A	b_A	CCF	m_C	b_C
Cadmium	0.944*	1.128	-3.6867	0.909*	0.7852	-2.715
Copper	0.960	0.9422	-1.700	0.960	0.8545	-1.702
Lead	0.791*	1.2730	-1.460	0.791*	1.2730	-4.705
Zinc	0.978	0.8473	0.884	0.986	0.8473	0.884

* The ACF and CCF for cadmium and lead are hardness dependent. Conversion factors are based on a hardness of 100 mg/L

2.1.3 Antidegradation. State Board Resolution 68-16, 'Statement of Policy with Respect to Maintaining High Quality Water" in California, known as the "Antidegradation Policy," protects surface and ground waters from degradation. Any actions that can adversely affect water quality in all surface and ground waters must be consistent with the maximum benefit to the people of the state, must not unreasonably affect present and anticipated beneficial use of such water, and must not result in water quality less than that prescribed in water quality plans and policies. Furthermore, any actions that can adversely affect surface waters are also subject to the federal Antidegradation Policy (40 CFR 131.12). The proposed TMDL will not degrade water quality, and will in fact improve water quality as it is designed to achieve compliance with existing water quality standards.

2.2 Water Quality Data Review

This review section summarizes water quality data used to develop this TMDL. The summary includes data considered by the Regional Board and EPA in developing the 1998 and the 2002 303(d) listings for metals and additional data submitted by the City of Los Angeles and the County of Los Angeles.

To assess water quality in the Los Angeles River, we evaluated dry-weather data collected by the City of Los Angeles as part of their NPDES monitoring requirements for Tillman and Los Angeles-Glendale wastewater treatment plants and data collected by the City of Burbank near the Burbank wastewater treatment plant. The City of Los Angeles measures metals and hardness in receiving waters from several locations upstream and downstream of its treatment plants (Figure 2) on a quarterly basis. The City of Burbank has a similar program and samples water quality in the Burbank Western Channel on a quarterly basis. These data were compared to the hardness adjusted dissolved criteria in the CTR using the hardness value for each sample. As both agencies analyze for concentrations of total metals, the comparison of their data to the dissolved criteria provides a conservative assessment of water quality impairment. These NPDES monitoring programs provide water quality information for Reaches 3, 4 and 5 of the Los Angeles River and the Burbank Western Channel, the results of which are summarized in Tables 5 and 6.

Table 5. Summary of ambient water quality data from NPDES monitoring programs for total metals relative to chronic dissolved criteria. Values in table reflect number of samples exceeding the chronic criteria over the total number of samples (Values below detection levels counted as zero).

Metals by Reach	LA River Reach 5	LA River Reach 4	LA River Reach 3	Burbank Western Channel
Cadmium	0/16	0/36	0/54	1/96
Copper	1/17	18/34	6/51	41/96
Lead	2/17	12/34	6/48	2/96
Zinc	0/17	0/34	0/51	1/96

Table 6. Summary of ambient water quality data from NPDES monitoring programs for total metals relative to acute dissolved criteria. Values in table reflect number of samples exceeding the acute criteria over the total number of samples (Values below detection levels counted as zero).

Metals by Reach	LA River Reach 5	LA River Reach 4	LA River Reach 3	Burbank Western Channel
Cadmium	0/16	0/34	0/42	0/96
Copper	0/18	4/36	0/51	10/96
Lead	0/17	0/34	0/48	0/96
Zinc	0/17	0/34	0/51	1/96

In January 2002, the City of Los Angeles began their Watershed Monitoring Program (WMP) which involves the collection of water quality data at eight stations along the Los Angeles River. In this program, water quality samples are analyzed for both total and dissolved metals at eight stations along the entire length of the River. We assessed data collected through May 2003. These data provide information on spatial variability in water quality in all six reaches of the Los Angeles River (Figures 3a-3d) but cannot be used to assess compliance with CTR criteria because hardness data were not collected.

We also evaluated the results of stormwater data collected by LACDPW as part of the NPDES municipal stormwater permit monitoring requirements. The LACDPW has been sampling approximately five storms per year at the Wardlow gage station since 1996. They sample hardness and metals (both dissolved and total) from composite stormwater samples. The results of these data are summarized in Table 7.

Table 7. Summary of stormwater data for dissolved metals (except selenium) relative to chronic and acute dissolved criteria. Data is from LACDPW station at Wardlow (Los Angeles River Reach 1) between 1996 and 2002. Values in the table reflect number of samples exceeding the criteria over the total number of samples.

Metal	# >Detection Level	Number > Chronic Criteria	Number > Acute Criteria
Cadmium	3/42	3/42	3/42
Copper	32/42	19/42	13/42
Lead	11/42	11/42	4/42
Selenium-Total	1/42	NA	0/42
Zinc	18/42	6/42	6/42

Cadmium – The Burbank Western Channel and Reach 1 of the Los Angeles River (from Carson Street to the estuary) are listed for cadmium. Based on our review of the data there are zero exceedances of the CTR limits, when adjusted for hardness, for cadmium during dry weather in Reaches 3, 4 or 5 of the Los Angeles River. There are some apparent exceedances of chronic criteria in the Burbank Western Channel. For a large number of samples, the reporting limit exceeded the chronic criteria. The chronic criteria for these samples ranged from 3.4 to 9.4 µg/L based on hardness values that ranged from 177 to 662 mg/L as calcium carbonate. Out of 96 samples, 21 had reporting levels greater than 10 µg/L and 20 had reporting levels greater than 5 µg/L. Discounting these from our analysis, we found that only 1 out of 96 samples exceeded the criteria. Lower detection limits were achieved in the City's Watershed Monitoring Program (WMP). They were able to detect concentrations as low as 0.2 µg/L in this data set. Total cadmium was detected in 12 out of 136 samples. The maximum cadmium concentration was 1.45 µg/l. Our review of the stormwater data collected at Los Angeles River Reach 1 (Table 7) indicates occasional exceedances of the chronic and a few exceedances of the acute criteria. These results appear to confirm the listings for cadmium.

Copper – The listings for copper are in Tujunga Wash, Rio Hondo (Reach 1), and Compton Creek. In the 2002 303(d) list, a copper listing was added for Reach 1 of the Los Angeles River based on stormwater data. San Pedro Bay is also listed for copper (AU# 78) based primarily on sediment concentrations. The data from the POTWs (Table 5 and 6) indicate that there are exceedances of both the chronic and acute criteria in the Los Angeles River (Reaches 3, 4 and 5) and in the Burbank Western Channel. In the City's WMP, measurable concentrations of total copper were detected in 126 out of 136 samples. Looking at the spatial trends in the WMP data (Figure 3b), the median concentration increased from 16 to 20 µg/l at the Sepulveda Boulevard station (downstream of the Tillman Plant), decreased to approximately 15 µg/l in the Glendale Narrows, and decreased to approximately 10 µg/l in the lower reaches of the river. The range of values gives some indication of the variability in the data (Figure 3b). The stormwater data from Reach 1 of the Los Angeles River indicates exceedances of both the acute and chronic values. There are no new data for Tujunga Wash, Rio Hondo or Compton Creek.

Lead – The lead listings are for Monrovia Canyon Creek, Rio Hondo (Reach 1), Compton Creek, and the Los Angeles River (Reaches 4, 2 and 1). Although not addressed specifically in this TMDL, the Los Angeles Harbor is listed for lead (AU# 75). In addition, the Los Angeles River Estuary (Queensway Bay) was listed for lead in sediment in 2002. EPA's review of the dry-weather data indicates occasional exceedances of the chronic standard in Los Angeles River (Reaches 3, 4, and 5) and Burbank Western Channel (Table 5). The reporting levels for lead in many of the samples from the Burbank Western Channel were higher than the chronic standard, complicating the assessment. For instance, out of the 96 lead measurements we evaluated, there were three instances when the reporting levels were greater than 100 µg/l, 19 instances when the reporting levels were greater than 50 µg/l, and 19 instances when the reporting levels were greater than 5 µg/l. Exceedances of these reported detection levels were not counted in Table 5 as exceedances of the chronic criteria. The chronic criteria for these samples ranged from 4.6 to 18 µg/L based on hardness values that ranged from 177 to 662 mg/L as calcium carbonate. High detection levels were not an issue in comparing reported data with the acute standard (Table 6). There were no exceedances of the acute standard in samples from the Burbank Western Channel or Reaches 3, 4 or 5 of the Los Angeles River. The variability in the lead concentration can be seen in the City's WMP data. Total lead concentrations were below detection limits in 71% of the samples. However, when detected, the lead concentrations could be quite high (Figure 3c). Based on the LACDPW data there were exceedances of both the acute and chronic standard in Reach 1 of the Los Angeles River during storms (Table 7).

Zinc – The Rio Hondo is listed for zinc. In 2002, a listing for dissolved zinc was added for Reach 1 of the Los Angeles River, based on the LACDPW stormwater data, and a listing for zinc in sediment was added for the Los Angeles River Estuary (Queensway Bay). Although not specifically addressed in this report, the Los Angeles Harbor and San Pedro Bay are both listed for zinc (AU #75 and AU #78). Based on data collected near the POTWs there does not appear to be any exceedances either of the acute or chronic zinc criteria in Reaches 3, 4 and 5 of the Los Angeles River (Tables 5 and 6). There was one exceedance of the acute and chronic standard out of the 96 samples analyzed from the Burbank Western Channel. The City's WMP detected total zinc in 91% of samples. Median zinc concentrations increased from 16 µg/l to approximately 64 µg/l in the area around the Tillman Plant (Figure 3d). In the reaches downstream, zinc concentrations were approximately 50 µg/l. In general, the zinc data are variable but low when compared to standards. There are no new data for the Rio Hondo. There do appear to be some exceedances of the zinc standard in Reach 1 of the Los Angeles River during storms (Table 7).

Aluminum – This is not part of analytical unit #13, but aluminum was added in 2002 based on LACDPW stormwater data. The total aluminum value was compared to the maximum contaminant level (MCL) of 1 mg/L. The MCL was exceeded in only 2 out of 26 stormwater samples collected since the year 2000. There are no data on dry-weather aluminum concentrations in any of the reaches of the Los Angeles River. Although the MCL has been incorporated into the Basin Plan to protect the MUN beneficial use, conditional designations are not recognized under federal law and are not water quality standards requiring TMDL development at this time. (See Letter from Alexis Strauss [USEPA] to Celeste Cantú [State Board], Feb. 15, 2002.)

Selenium – Aliso Creek was listed for selenium on the 1998 303(d) list. In 2002, two more tributaries (McCoy Canyon Creek and Dry Canyon Creek) were listed for selenium. We analyzed selenium data collected by the City of Calabasas on a monthly basis between July 2000 and July 2002 as part of a 319h grant provided by the Regional Board. At the two stations in McCoy Canyon Creek, the CTR value of 5 µg/l was exceeded in 27 out of 29 samples. The maximum measured value was 44 µg/l. The selenium values were lower at the two Dry Canyon Creek stations. At these stations, values greater than 5 µg/l were observed in 12 out of 54 samples. We also assessed selenium data collected by the City of Los Angeles at eight stations along the Los Angeles River in 2002 and 2003 as part of their Watershed Monitoring Program. Selenium values greater than 5 µg/l were observed in 14 out of 136 samples. All of these were from the Los Angeles River Reach 6 (where 14 out of 17 exceeded the CTR value). None of the other samples from any of the downstream stations on the Los Angeles River exceeded the CTR value. The selenium issue seems to be confined to the upper reaches of the watershed and tributaries draining to Reach 6. Because much of the area is open space and there is little industrial activity, we believe that the selenium in the waterbody originates from natural sources such as marine shales (EDAW, 2003).

EPA and the Regional Board have funded the Southern California Coastal Water Research Project (SCCWRP) to evaluate background loadings of metals and other parameters from natural sources in Southern California. We also note that EPA is in the process of re-evaluating the selenium standard for the protection of aquatic life use support. Further investigation on the sources and the appropriateness of applying the CTR standard is warranted prior to establishing a selenium TMDL for these reaches. We propose rescheduling development of the selenium TMDL for the Los Angeles River Reach 6 to coincide with the selenium TMDLs for the newly listed segments.

Conclusions. Our review of the data indicates that there are occasional exceedances of copper and lead during dry-weather conditions. A single exceedance for cadmium was identified in the Burbank Western Channel during dry weather. There are also occasional exceedances of CTR criteria in stormwater for copper, lead and to a lesser extent for zinc and cadmium. Copper, lead and zinc also appear to be an issue in sediments of Los Angeles Harbor and San Pedro Bay. High selenium values were only observed in the dry-weather at stations located in the upper portion of the watershed, which we believe are associated with natural sources. Finally, we find that a TMDL for aluminum is not warranted to protect a conditional use.

3. NUMERIC TARGETS

Numeric targets for the TMDL have been calculated based on the numeric standards in the CTR. Separate targets were developed for dry and wet weather because hardness values and flow conditions in the Los Angeles River and tributaries vary between the dry and wet weather.

The numeric standards in the CTR are expressed in terms of dissolved metals (USEPA 2000a) because the dissolved forms are the most bioavailable to aquatic organisms. However, we recognize the potential for transformation between total metals measurement and the dissolved metals fraction. Therefore, this TMDL specifies numeric targets in terms of the dissolved fraction of metals, but provides conversion factors to translate the dissolved targets to total metals pollutant allocations. We also recognize that total metals loadings may have to be controlled in the future to address metals listings in San Pedro Bay near Cabrillo Pier (listed for copper, chromium, and zinc under analytical unit #78) and the Los Angeles River Estuary (listed for lead and zinc in sediment on the 2002 303(d) list). Although efforts to reduce metal loadings to the Los Angeles River will result in reductions of metals loadings to the estuary and to the bay, the targets are not designed to address sediment metals listings. San Pedro Bay also receives substantial metals loadings from a number of sources in both Dominguez Channel and San Gabriel River Watersheds. These listings would be better managed through a coordinated TMDL effort in the estuary that addresses the metals loadings from these three watersheds to the estuarine and coastal waters of San Pedro Bay, Los Angeles/Long Beach Harbor, Dominguez Channel and Los Coyotes Channel.

3.1 Dry-Weather Targets

As discussed in Section 2 of this TMDL, the metals criteria in the CTR are dependent on the hardness of the receiving water. To establish receiving water hardness, we evaluated hardness data collected by the three POTWs in the ambient water upstream and downstream of the plants (Table 8). This includes data that were collected by Larry Walker and Associates as part of a study to determine site-specific translators for dissolved copper downstream of the Tillman and Glendale POTWs. Information for Reaches 1 and 2 of the Los Angeles River and the listed tributaries was obtained from the LACDPW which had dry-weather hardness data from samples collected between 1988 and 1995 for the entire river. To assess the comparability of these older data, we compared the historic hardness data associated with Reaches 4 and 3 collected by LACDPW with the more recent data collected by the Tillman and Glendale POTWs in these same reaches. The results from the two data sets were extremely close (within 10 mg/), suggesting that the older data from 1988 to 1995 are comparable to the newer data and therefore appropriate for setting numeric targets. Hardness values were not available for the Arroyo Seco or the Tujunga Wash.

Table 8. Summary of hardness data for specific reaches of the Los Angeles River during dry weather. Values reported in mg/L as calcium carbonate.

River Reach	Number of measurements	10^{th} Percentile	Median	90^{th} Percentile
LA River Reach 5. Above Tillman LAR-9	40	608	702	832
LA River Reach 4. Below Tillman LAR-7,8	69	196	246	400
LA River Reach 3. Above Glendale LAG-7	17	232	282	330
LA River Reach 3. Below Glendale LAG-4,5	69	242	278	322
Western Channel Above Burbank (Station 1)	41	272	326	395
Western Channel Below Burbank (Station 1.5, 2 and 5)	61	197	229	275
LA River Reach 2	83	221	268	322
Rio Hondo Reach 1	74	111	141	199
LA River Reach 1	82	219	282	340
Compton Creek	65	148	225	296
Monrovia	81	182	209	239

Consistent with the Policy for Implementation of Toxics Objectives for Inland Surface Waters, Enclosed Bays, and Estuaries, or SIP, (SWRCB, 2000a), the target for the chronic criteria was based on the 50^{th} percentile of the hardness data for each reach and the target for the acute criteria was based on the 10^{th} percentile of the hardness data for each reach (Table 9). Targets for Tujunga Wash and Arroyo Seco were based on hardness values in the Los Angeles River Reaches 4 and 3, respectively. For four of the five metals, the chronic criteria were the most-limiting value and will be used as the basis for developing load allocations for dry weather. The exception was zinc, where the acute was the most limiting criterion.

Table 9. Numeric targets for TMDL during dry weather, expressed as dissolved metals (adjusted for hardness by reach). Chronic target is set using the 50th percentile for hardness. Acute target is set using the 10th percentile for hardness. (Maximum hardness value correction is 400 mg/L) Targets reported as µg/L.

Metal	Cadmium		Copper		Lead		Zinc	
	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute
LA Reach 5	6.2	19.1	29	50	11	281	382	379
LA Reach 4 and Tujunga Wash	4.3	8.8	19	25	6.6	133	253	207
LA Reach 3 Above LAG WRP	4.8	10.6	22	30	7.6	159	284	239
LA Reach 3 and Arroyo Seco	4.8	11.1	22	28	7.5	167	281	248
Burbank (above Burbank WTP)	5.4	12.6	25	31	8.9	188	322	274
Burbank (below Burbank WTP)	4.1	8.9	18	26	6.1	134	238	208
LA Reach 2	4.7	10.1	21	28	7.3	151	274	229
LA Reach 1	4.8	10.0	22	28	7.6	150	283	228
Compton Creek	4.1	10.3	18	29	6.0	154	235	233
Rio Hondo	2.9	4.8	12	15	3.7	72	158	128
Monrovia Canyon Creek	3.9	8.2	17	24	5.6	123	221	195

The chronic criteria are typically based on exposures that occur over a 4-day time interval. The acute criteria are typically based on a 1-hour exposure time and are more appropriate for setting targets for storm-related conditions.

We evaluated the potential for development of site-specific translator values to convert between dissolved and total metals concentrations using existing data collected by the City's WMP (Table 10). To establish the relationship we regressed dissolved concentrations against total concentrations. The slope reflects the ratio of the dissolved to total concentration; the r-squared value reflects the strength of the relationship.

Table 10. Relationship between dissolved and total metals in dry-weather data. CTR value reflects conversion factor in California Toxics Rule. Dry weather values for Los Angeles River are from data provided by City of Los Angeles WMP (2002 – 2003).

Metal	CTR Default Translator	Dry-Weather Data (City of Los Angeles)		
		N	Slope	R^2
Cadmium	0.91 – 0.94	16	0.94	0.99
Copper	0.96	136	0.81	0.78
Lead	0.79	29	0.45	0.40
Zinc	0.98	136	0.93	0.99

These data suggest that during dry-weather conditions, the metals are predominantly in the dissolved form. Lead appears to be the exception. We caution that the data used in these regressions were not screened for outliers. The relationship may also be influenced by detection limit issues.

The City of Los Angeles proposed local dry-weather translator numbers for copper for the areas downstream of the Tillman Plant (Reach 4) and the Glendale Plant (Reach 3) based on a study performed by Larry Walker and Associates (LWA). Total and dissolved copper concentrations were measured at a number of in-stream stations downstream of the plants on six dry-weather days. Dissolved-to-total copper ratios were calculated and separate translator values were proposed for development of acute and chronic criteria based on the 50th and 90th percentile values of the ratios. For the area downstream of the Tillman Plant, the proposed translators for copper were 0.57 for chronic and 0.72 for acute. For the area downstream of the Glendale Plant, the proposed translators were 0.77 for chronic and 0.84 for acute. To assess the strength of the relationship in the LWA data, EPA regressed the dissolved to total data. That regression was strong for the Glendale data (R^2 = 0.94) but weak for the Tillman data (R^2 = 0.20). Suspecting that relationship may be affected by total suspended solids, LWA re-analyzed the data to account for the partitioning of the copper between the dissolved and particulate range. Based on this analysis, LWA proposed partition coefficients for use as copper translators. This appeared to provide a better fit for the data. For Tillman, the proposed translator is 0.74 for chronic and 0.92 for acute. For Glendale the proposed translators are 0.80 for chronic and 0.89 for acute. Although it is clear that during dry-weather conditions a large fraction of the total metals is in the dissolved form, the exact relationship is unclear. However, we believe that these values provide a reasonable approximation of the partitioning of copper between dissolved and particulate phase. We propose to use the partition coefficients as a translators for copper in this TMDL. Further study will be required to evaluate and refine the translators.

For copper in the remaining reaches and the other metals in all reaches we propose to use the conversion factors in the CTR as default translator values. These values are more conservative than estimates based on the slope of the regressions from pair-wise comparisons (Table 10). Although application of these default values may be a conservative assumption for the Los Angeles River, this conservative assumption is applied to the margin of safety for the TMDL.

We are aware that the City of Los Angeles collected data beyond hardness and translator-related parameters to support application of an alternative method for determining site-specific copper water quality criteria in their copper translator study. This alternative method, called the Biotic Ligand Model (BLM), is currently being considered by U.S. EPA. This TMDL will include a re-opener to allow for application of site specific-water quality criteria for copper if the BLM model is approved by U.S. EPA and the Regional Board.

3.2. Wet-Weather Targets

In this section we first define wet-weather condition in terms of flow and then define the wet-weather target in terms of hardness. Stormwater dominates the flows in the Los Angeles River when it rains. Although there is a good relationship between rain and river flow, the strength of this relationship is weaker for the smaller storms, largely because smaller storms are more localized. For instance, small storms in the upper undeveloped portion of the watershed may not contribute any flow to the lower reaches of the river. For the purpose of this TMDL, we define the wet-weather condition in terms of flow rather than rain. We operationally define the wet-weather condition as flows greater than 500 cfs. This is based on the upper 10th percentile of flows as measured at Wardlow (500 cfs) over a 12-year period. Figure 10 illustrates the inflection at the upper 10^{th} percentile of flows. Storms of this duration are rare in Southern California. Most storms are of shorter duration (Ackerman & Weisberg, 2003). For the wet-weather target we evaluated hardness values from the stormwater data collected by LACDPW at

Wardlow. These data represent composite samples from 42 storms between 1996 and 2002. Potential targets based on the 10th, 50th and 90th percentile of the hardness data are presented below (Table 11). We propose targets based upon the 50th percentile hardness number because it is representative of the average stormwater conditions.

Table 11. Range of potential numeric targets for wet weather, expressed as dissolved metals. Numbers are based on percentile values for hardness from LACDPW stormwater samples collected at Wardlow (1996-2002). The recommended targets for the TMDL are based on the 50th percentile hardness value of samples from 42 storms.

Metal	Acute target based on 10th percentile hardness (34 mg/L)	Acute target based on 50th percentile hardness (80 mg/L)	Acute target based on 90th percentile hardness (126 mg/L)
Cadmium	1	3	6
Copper	5	11	17
Lead	20	51	83
Zinc	47	97	143

To evaluate the potential for site-specific wet-weather translators to convert between dissolved and total metals concentrations, we evaluated stormwater data collected by the LACDPW at the mass emission station at Wardlow. To establish the relationship, we regressed dissolved metals against total metals concentrations in the stormwater data set (Table 12). The slope reflects the ratio of the dissolved to total concentration; the r-squared value reflects the strength of the relationship.

Table 12. Relationship between dissolved and total metals in stormwater data. CTR value reflects conversion factor in California Toxics Rule. Stormwater values for Los Angeles River are from LACDPW data (1996-2002)

	CTR Default Translator	Wet-Weather Data (LACDPW)		
Metal		**N**	**Slope**	**R^2**
Cadmium	0.91 – 0.94	3	-	-
Copper	0.96	33	0.65	0.69
Lead	0.79	13	0.82	0.98
Zinc	0.98	20	0.61	0.61

These regressions suggest that the CTR default translators generally overestimate the dissolved portion of metals in stormwater. Data from literature suggest that an even greater portion of metals is associated with particulates in wet weather. Young et al. 1980 estimated that the 90% of the cadmium, copper, lead, and zinc in stormwater samples were associated with the particle phase. McPherson et al. 2004 found similar results in stormwater from nearby Ballona Creek. In that study 83% of the cadmium, 63% of the copper, and 86% of the lead were associated with the particle phase. Use of the CTR default values would be overly conservative, we therefore propose using slope of the regression as translators for copper, lead and zinc. The CTR default translator is used for cadmium.

4. SOURCE ASSESSMENT

In the context of TMDLs, pollutant sources are either point sources or nonpoint sources. Point sources typically include discharges for which there are defined outfalls such as wastewater treatment plants and industrial discharges. These discharges are regulated through a permit such as the federal National Pollution Discharge Elimination System (NPDES) permit or the State of California issued Waste Discharge Requirements (WDRs). Nonpoint sources, by definition, include pollutants that reach waters from a number of diffuse land uses and source activities.

The distinction between point and nonpoint sources is not always clear in the Los Angeles River area. For example urban runoff in Los Angeles County is regulated under three stormwater NPDES permits. The first is the County of Los Angeles Municipal Stormwater NPDES permit (MS4 permit). There are 85 co-permittees covered under this permit, including 84 cities and the County of Los Angeles. The second is the City of Long Beach MS4 permit. The third is a separate statewide stormwater permit specifically for the California Department of Transportation (Caltrans). There are a large number of small industrial wastewater dischargers with NPDES permits throughout the watershed. Runoff from industrial facilities is also subject to a statewide NPDES stormwater permit for industry. The permitting process defines these discharges as point sources because the stormwater discharges from the end of a stormwater conveyance system. There is a statewide NPDES stormwater permit for construction activities as well. Because stormwater discharges are permitted under NPDES permits, they are treated as point sources in this TMDL.

Nonpoint source is, by definition, runoff that is not covered under any of the stormwater permits. An example of this would be the runoff from the National Forest and State Parks. While not subject to a permit, the contribution of runoff from these exempted areas must be dealt with in the TMDL. This can be done through the development of specific allocations for the National Forest and the State Parks or by treating the runoff from these areas as background in the TMDL calculation.

There are several POTWs that either discharge, or have the potential to discharge into the Los Angeles River or listed tributaries. The three largest POTWs (Donald G. Tillman Water Reclamation Plant, Los Angeles-Glendale Water Reclamation Plant, and Burbank Water Reclamation Plant) constitute the major sources in the watershed.

- Tillman is a tertiary treatment plant with a design capacity of 80 mgd. Most of the flow is discharged directly into the Los Angeles River (Reach 4). However, a portion of the flow goes into a recreation lake, which then drains into Bull Creek and Hayvenhurst Channel and back into the Los Angeles River (Reach 5). Another portion of the flow goes to a wildlife lake, which then drains into Haskel Channel and ultimately back into the Los Angeles River (Reach 5). The Tillman plant discharges around 53 mgd to the Los Angeles River.

- The Los Angeles-Glendale POTW is a 20-mgd plant that discharges approximately 13 mgd directly into the Reach 3 of the Los Angeles River in the Glendale Narrows. Approximately 4 mgd of the treated wastewater is used for irrigation and industrial uses.

- Burbank has a design capacity of 9 mgd. Approximately 4 mgd is discharged directly into the Burbank Western Channel. The City of Burbank and Caltrans reclaim a portion of the effluent for irrigation (freeway landscapes, golf courses, parks etc.). Treated water from the plant is also used as cooling water for the Burbank Steam Power Plant.

- The Tapia Water Reclamation Facility (Tapia) is a 16-mgd plant that discharges into Malibu Creek. However, due to a discharge prohibition in Malibu Creek from April 15 to November 15, the permittee is allowed to discharge up to 1 mgd of wastewater to the Los Angeles River. However, this discharge is infrequent. The permitted flow from the Tapia is less than 2% of the mean flows from the major POTWs discharging to the Los Angeles River.

- The Whittier Narrows Water Reclamation Plant discharges to the Rio Hondo above the Whittier Narrows Dam, into spreading grounds where most of the effluent enters the groundwater. It has been estimated that less than 1% (0.1mgd) of Whittier Narrows WRP effluent remains in the channel downstream of the spreading grounds.

- The Los Angeles Zoo Wastewater Facility has a 1.8 million gallon retention basin, and discharges into Reach 3 of the Los Angeles River near the Glendale Narrows only during wet weather when the retention capacity is exceeded.

The total metals loads from the Tillman, Burbank and Glendale WRPs were estimated using monthly flow and effluent concentration data provided as part of the annual self monitoring reports (Table 13). We estimate that on a daily basis these three POTWs contribute approximately 0.2 kg/d of cadmium, 4.5 kg/d of copper, 0.5 kg/d of lead and 12.8 kg/d of zinc to the Los Angeles River.

Table 13. Total annual metals loadings from three POTWs (kg/yr).

Metal	Facility	1998	1999	2000	2001	2002	Ave
Cadmium	Tillman	105	59	53	33	33	57
	Burbank2	7	4	14	13	1	8
	Glendale	19	16	15	16	16	16
	Total	**131**	**79**	**82**	**62**	**50**	**81**
Copper	Tillman	1427	1292	1690	1574	1260	1449
	Burbank2	27	24	37	8	66	32
	Glendale	119	135	166	205	150	155
	Total	**1573**	**1451**	**1893**	**1787**	**1476**	**1636**
Lead	Tillman	122	105	120	94	86	105
	Burbank2	46	26	64	95	3	47
	Glendale	29	30	32	24	24	28
	Total	**197**	**161**	**216**	**213**	**113**	**180**
Zinc	Tillman	4134	2955	4398	3671	2994	3630
	Burbank2	157	138	238	353	207	219
	Glendale	1002	814	771	801	749	827
	Total	**5293**	**3907**	**5407**	**4825**	**3950**	**4676**

During low flow periods these three major POTWs typically account for 60% to 80% of the total volume of discharge in the river. The remaining 20% to 40% of the dry weather flow represents a combination of tributary flows, groundwater discharge, flows from permitted NPDES discharges within the watershed (Table 14), and dry-weather urban runoff.

Table 14. Summary of permits in Los Angeles River watershed. Pollutant allocations given in parenthesis.

Type of Permit	No. of Permits
Publicly Owned Treatment Works (mass and concentration-based waste load allocations)	6
Municipal Stormwater (mass-based waste load allocations)	3
Industrial Stormwater (concentration-based waste load allocations)	1307
Construction Stormwater (concentration-based waste load allocations)	204
Minor NPDES Discharges (concentration-based waste load allocations)	28
General NPDES Discharges (concentration-based waste load allocations)	
Construction Dewatering	33
Treated Groundwater from Construction Dewatering	9
Petroleum Fuel Cleanup Sites	12
VOCs Cleanup Sites	6
Hydrostatic Test Water	12
Non-Process Wastewater	15
Potable Water	17
Total	**1652**

To assess the relative contributions of metals during dry weather, sampling was conducted in September 2000 and July 2001. The monitoring consisted of synoptic sampling of flow and concentration from the three POTWs, the headwaters of the tributaries, and 49 storm drains on September 11-12, 2000 (Ackerman et al., 2003). This was followed up by another synoptic survey in July 2001. In this second survey, more focus was put on the storm drains, and the number of storm drains sampled during this event was 84. This monitoring reflects one of the most complete efforts to identify and quantify dry-weather flows from storm drains in Southern California. Table 15 provides the summary results from these two surveys in terms of total mass for each metal and the relative contribution from each major source.

Table 15. Relative loading (%) of total metals by source to the Los Angeles River during dry-weather conditions (Tetra Tech, 2000, 2001).

Sources	Cadmium		Copper		Lead		Zinc	
	2000	2001	2000	2001	2000	2001	2000	2001
Tributaries	7%	6%	8%	5%	10%	6%	5%	3%
POTWs	59%	39%	69%	38%	55%	41%	81%	51%
Dry Weather Runoff	34%	55%	23%	57%	35%	53%	14%	46%
Total Mass (kg/d)	0.3	0.3	5.6	6.9	2.8	2.4	14.8	20.4

Although there is some variability in the data, the POTWs contribute a fairly large percentage of the total dry-weather metals loadings. The concentrations of metals in the POTWs may be low, but loadings are high because the POTW flows are large. The storm drains also contribute a large percentage of the loadings. Storm drain flows are typically low during dry weather, but concentrations of metals in urban runoff may be quite high.

During dry weather, background concentrations may come from tributaries which drain the hills of the Angeles National Forest and the open areas of the Santa Monica Mountains. The flows from these areas during dry weather are relatively small and much of it is captured behind dams. The concentrations of metals from the tributary sampling also tended to be low. We estimated that the loadings from the tributaries were generally less than 10%. This may be an overestimate, since the sites for the tributary samples were not selected for the purpose of defining natural background conditions. Rather, sites were selected to define boundary conditions for model development and thus are likely to have inputs from storm drains upstream of the model boundary. EPA and the Regional Board are currently funding research in Southern California to provide better estimates of background loadings from natural sources.

In this source analysis, non-detects were treated as ½ the detection limit. The estimates of total mass loadings and relative contributions would be quite different if we had treated the detection limits as zeros or as equal to the detection levels. This is particularly true for lead and to a lesser extent for cadmium, which were generally below detection limits on both sampling dates. We did not treat detection limits as zeros in the source analysis because these metals have been frequently detected in the effluent from the three POTWs and in dry-weather urban runoff, as reported by LACDPW.

Although the dry-weather loadings of metals may be significant in certain years, most of the annual metals loadings to the Los Angeles River are associated with wet weather. A recent study found that during the 2000-01 and 2001-02 seasons, 100% of the lead and approximately 40% of the copper and zinc loadings resulted from stormwater runoff (Stein, et al., 2003). In addition to the MS4 and Caltrans stormwater permits, there are more than one thousand industrial facilities in the Los Angeles River watershed that are enrolled under the statewide NPDES general stormwater permit for industry (Table 13). Those facilities are required to sample runoff and report monitoring data twice annually. A review of the available monitoring data demonstrates that several industrial facilities are exceeding applicable CTR values and are therefore a source of metals loadings to the Los Angeles River. However, the data collected under this program are not of sufficient frequency or quality to be used to estimate loadings (Duke et al., 1998). Therefore, to assess total stormwater loadings we relied on the LACDPW stormwater monitoring data from the mass emission station at Wardlow (LACDPW, 2000). Table 16 summarizes the aggregate seasonal loads from flow-weighted composites of multiple storms sampled between 1996 and 2002.

Table 16. Seasonal stormwater total metals loadings (kg/yr) to Los Angeles River watershed. Data are from LACDPW and SCCWRP.

LACDPW	Cadmium	Copper	Lead	Zinc
96/97	-	3,629	3,760	16,692
97/98	-	36,741	94,347	210,012
98/99	-	1,075		6,078
99/00	-	286	207	1,012
00/01	-	1,409	879	5,645
01/02	-	514	106	1022
Average	-	7,276	19,860	40,077
SCCWRP	**Cadmium**	**Copper**	**Lead**	**Zinc**
Typical year	62	6,960	2,304	42,479

These data are highly variable with seasonal loadings that can vary by an order of magnitude depending on the rainfall and size of storms in a given year. In a report to the State Water Resources Control Board, SCCWRP estimated the mass loadings for a typical year (Ackerman and Schiff, 2003). These values are generally consistent with the average loadings calculated from the LACDPW mass emission stations.

To estimate the relative contributions on an annual basis, we can compare the stormwater loadings from the SCCWRP estimate from a typical year (Table 16) to the average POTW loading (Table 13). On an annual basis, stormwater contributes about 40% of the cadmium loading, 80% of the copper loading, 95% of the lead loading, and 90% of the zinc loading.

Atmospheric deposition is another potential source of metals to the watershed. (Sabin et al., 2004). Deposition of metals to the surface area of the Los Angeles River watershed may be substantial, on the order of several thousand kilograms per year (Stein et al., 2003). To assess the impact of these loadings on the Los Angeles River, we separate direct atmospheric deposition from indirect deposition. Direct atmospheric deposition can be quantified by multiplying the surface area of the river times the rate of atmospheric deposition. These numbers (Table 17) are generally small because the actual surface area of the river system is small. Direct deposition of metals is insignificant relative to either the annual dry-weather loadings or the total annual loadings. Indirect atmospheric deposition reflects the process by which metals deposited on the land surface may be washed off during rain events and be delivered to the Los Angeles River and tributaries. Not all the metals deposited on the land from the atmosphere are loaded to the river. The mass loading in stormwater is typically 10 to 20% of the mass loading from atmospheric deposition (compare Table 16 and Table 17). The loadings of metals associated with indirect atmospheric deposition are accounted for in the estimates of the stormwater loadings.

Table 17. Estimates of direct and indirect deposition (kg/year)

Type of deposition	Copper	Lead	Zinc
Indirect	18,000	13,000	88,000
Direct	3	2	1

5. LINKAGE ANALYSIS

Information on sources of pollutants provides one part of the TMDL equation. To determine the effects of these sources on water quality, it is also necessary to determine the assimilative capacity of the receiving water. The delivery of metals to the Los Angeles River and the assimilative capacity of the river to accommodate these loadings so that standards are met can be strongly affected by variations between wet and dry weather. Given the differences in sources and flows between dry- and wet-weather, we developed two distinct approaches. This section describes the use of hydrodynamic and water quality models to assess the effects of metals loadings in the Los Angeles River on water quality under both dry and wet weather conditions.

5.1 Development of the Dry-Weather Model

The Environmental Fluid Dynamics Code 1-D (EFDC1D) was used to model the hydrodynamic characteristics of the river. The hydrodynamic model (EFDC) was utilized to simulate the flow and pollutant loading within the 303(d) listed segments of the Los Angeles River and tributaries (Table 18) under dry-weather conditions. EFDC1D is a one dimensional variable cross-section model for flow and transport in surface water systems. The river system was divided into a total of 302 grid cells averaging 600 meters in length. Detailed cross-sections of the 303(d) listed rivers and tributaries were input into the model.

Table 18. Los Angeles River segments modeled for linkage analysis

Los Angeles River Mainstem	Los Angeles River Tributaries
Reach 6: above Sepulveda Flood Control Basin	Bell Creek
Reach 5: within Sepulveda Basin	Tujunga Wash
Reach 4: Sepulveda Dam to Riverside Dr	Burbank Western Channel
Reach 3: Riverside Dr to Figueroa St	Verdugo Wash
Reach 2: Figueroa St to Carson St	Arroyo Seco
Reach 1: Carson St to Estuary	Rio Hondo River
	Compton Creek

To support the model development a comprehensive set of in-stream hydrodynamic and water quality data were collected over a two-day period in the late summer of 2000 (September 11-12) by SCCWRP and others. A second survey was conducted over a two-day period in summer of 2001 (July 29-30). The second survey provided an independent data set that would serve to validate the model. In addition, a special study was also conducted in September 2000 to evaluate the rate with which water flows through the system (Ackerman, 2003). The development and calibration of the dry-weather model system is presented in detail in a report entitled "Modeling Approach and Calibration Report for the Los Angeles River Basin Nutrient and Fecal Coliform TMDLs" (Tetra Tech, 2002), included as Appendix I. The linkage analysis is briefly summarized below.

5.1.1. Calibration and Validation of the Dry-Weather Model. There are four stream gages along the mainstem of the Los Angeles River (Figure 4). The upper-most station (designated F300-R) is in Reach 4 of the Los Angeles River below Tillman plant. The lowest station is the Wardlow gage station (designated F319-R), which is below the confluence of all tributaries within the Los Angeles River and all simulated point sources.

Figure 5 presents comparisons of the measured versus simulated flows at these four stations located along the mainstem of the Los Angeles River for September 11, 2000 and July 29, 2001. The first thing to notice is the daily variation in the in-stream flow measurements.
On September 11, 2000 the measured flows ranged from 50 to 120 cfs at the upper most station to 135 to 200 cfs at the lowest station. On July 29, 2001 the measured flow ranged from 50 and 75 cfs at the upper-most station and 170 to 200 cfs at the lowest station. Some of this variation may be associated with the inherent measurement error of the gages at low flows. The long-term median flows (12-year) at Tujunga, Firestone and Wardlow are 78 cfs, 124 cfs, and 145 cfs respectively. The days selected for the calibration and validation of the model are generally representative of the low-flow condition.

The flow data for September 11, 2000 was used to calibrate the dry-weather model (Table 19). A non-POTW base flow was established in calibration to account for unaccounted flows from headwaters, storm drains, groundwater discharge near the Glendale Narrows and other unknown sources. In the 2001 sampling, greater effort was put on characterizing storm drain flows. As a result, it was not necessary to add additional unknown flows (Table 19). The uncertainties in our understanding regarding the amount of groundwater discharge and storm drain flows must be acknowledged. In the 2000/01 water year it was estimated that about 3000 acrefeet/year of groundwater were discharged to the river at the Glendale Narrows. This equates to 5.4 cfs of groundwater discharged into the system. However, the timing, frequency and extent of this discharge are not known. The estimates of stormwater flow are also less precise than desirable. These limitations aside, the model appears to be providing a reasonable representation of the average dry-weather condition in the Los Angeles River. Comparison of the simulated flow (Figure 5) shows that the model is simulating the dry-weather flow relatively well.

Table 19. Flows (cfs) used in the calibration and validation of the dry-weather model.

Source	September 11, 2000	July 29, 2001
POTW Flow	71.8	46.1
Tributary Flow	19.5	12.8
Storm Drain Flow	46.6	65.1
Unknown	24.8	
Total Flow	162.7	124.0

For simulation of the water quality within the Los Angeles River, the EFDC model was linked to the Water Quality Analysis Simulation Program (WASP5). The dry-weather water quality model was calibrated using field measurements collected on September 10, and 11, 2000 (Tables 20 and 21). Inputs from the POTWs, storm drains, tributaries and boundary conditions were obtained by direct measurement. The storm drain flows and concentration data used in the model are summarized in Appendix I.

Table 20. Flow (cfs) and concentrations of total metals (µg/l) used in model calibration based on samples collected on September 10 and 11, 2000 for point source discharges.

Point Source Discharge	Flows	Cd	Cu	Pb	Zn
Tillman POTW					
Direct Discharge	53.3	0.5	13	5	39
Japanese Gardens	7.4	0.5	13	5	39
Recreation Lake	27.0	0.5	13	5	39
Wildlife Lake	9.1	0.5	13	5	39
Glendale POTW	14.4	0.5	5	5	30
Burbank POTW	14.3	5	18	5	52

Lead was not detected in any of the POTW flows and Cadmium was not detected in the flows from the Tillman or Glendale POTWs (Table 20). Non-detects were treated as ½ the detection limit. Cadmium was not detected in any of the tributary flow and lead was only detected in the flow from Verdugo wash (Table 21). Non-detects were treated as ½ the detection limit.

Table 21. Flows (cfs) and concentrations of total metals (µg/l) used in model calibration based on samples collected on September 10 and 11, 2000 for tributaries (includes storm drain contributions).

Point Source Discharge	Flows	Cd	Cu	Pb	Zn
Bell Creek	4.3	0.5	15	5	5
Tujunga Wash	0.7	0.5	18	5	16
Burbank Western Channel	1.4	0.5	18	5	52
Verdugo Wash	2.8	0.5	14	19	41
Arroyo Seco	3.7	0.5	5	5	5
Compton Creek	3.1	0.5	5	5	11

The dry-weather water quality model was validated using field measurements from July 29 and 30, 2001 (Tables 22 and 23). Inputs from the POTWs, storm drains, tributaries and boundary conditions were obtained by direct measurement. The storm drain flows and concentration data used in the model are summarized in Appendix I.

Table 22. Flows (cfs) and concentrations of total metals (µg/l) used in model validation based on samples collected on July 29 and 30, 2001 for point source discharges.

Point Source Discharge	Flows	Cd	Cu	Pb	Zn
Tillman POTW					
Direct Discharge	14.4	0.5	12.5	5	50.6
Japanese Gardens	7.0	0.5	5	5	35.1
Recreation Lake	27.0	0.5	14.7	5	67.2
Wildlife Lake	8.8	0.5	5	5	35.1
Glendale POTW	14.3	0.5	20.1	5	43.1
Burbank POTW	8.1	0.5	16.2	5	69.7

Cadmium and lead were not detected in any of the POTW flows (Table 20). Non-detects were treated as ½ the detection limit.

Table 23. Flows (cfs) and concentrations of total metals (µg/l) used in model validation based on samples collected on July 29 and 30, 2001 for tributaries (includes storm drain contribution).

Point Source Discharge	Flows	Cd	Cu	Pb	Zn
Bell Creek	2.7	0.5	6.9	5	5
Tujunga Wash	0.4	0.5	32.2	5	17.9
Burbank Western Channel	1.4	0.5	16.2	5	69.7
Verdugo Wash	2.2	0.5	17.9	5	25.3
Arroyo Seco	3.3	0.5	5	5	1.08
Rio Hondo	0.5	0.5	18.2	25.5	33.2
Compton Creek	1.8	0.5	9.2	5	24.9

Cadmium was not detected in any of the tributary flow. Lead was only detected in the flow from Verdugo wash (Table 21). Non-detects were treated as ½ the detection limit.

The model performs well in predicting the average concentrations of these metals (Figure 6b. validation). These can be compared to the long-term averages as represented by the City of Los Angeles Watershed monitoring program (Figures 3a – 3d). On both days, the model indicated that concentrations were below the CTR standards. This is consistent with our expectation, since the POTWs that provide most of the dry-weather flows to the river are generally discharging effluent that meets the water quality standards. The model is not able to represent all the temporal and spatial variability observed in the in-stream metals concentrations. This is likely due to the uncertainty and inherent variability in the estimates of storm drain flow and concentrations. The variability in concentrations seen over time in the City's data set suggests that episodic exceedances in water quality are likely to be a result of irregular inputs from urban runoff rather than the more stable POTW flow. The model provides a reasonable assurance that we understand the relationship between in-stream loads and targets.

5.2 Development of the Wet-Weather Model

Wet-weather sources are generally associated with wash-off of pollutant loads accumulated on the land surface. During a rainy period, these loads are delivered to the waterbody through creeks and stormwater collection systems. USEPA's Loading Simulation Program in C++ (LSPC) was selected to simulate the hydrologic processes and pollutant loading from the Los Angeles River watershed. LSPC is a recoded C++ version of USEPA's Hydrologic Simulation Program-Fortran (HSPF) that relies on fundamental algorithms (Bicknell et al., 1996). LSPC is a watershed modeling system that includes streamlined HSPF algorithms for simulating hydrology, sediment, and general water quality on land as well as a simplified stream transport model. LSPC has been successfully applied and calibrated in Southern California for the San Gabriel River, San Jacinto River and Coastal Watersheds in San Diego Region.

The Los Angeles River watershed area was divided into thirty-five smaller, discrete sub-watersheds for modeling and analysis (Figure 7). This subdivision was primarily based on the stream and storm sewer networks and topographic variability. Other factors considered in the subdivision included the presence of existing watershed boundaries (based on CalWater 2.2 watershed boundaries and municipal storm sewer-sheds), the locations of flow and water quality monitoring stations, and consistency of hydrologic factors and land-use patterns. Each delineated subwatershed was represented with a single stream reach from the National Hydrography Dataset (NHD) stream network. Information on the length, slope, mean depth and channel widths for each reach was used to route flow and pollutants through the hydrologically connected subwatersheds.

The watershed model requires a basis for distributing hydrologic and pollutant loading parameters among each of the sub-watersheds. This is necessary to appropriately represent hydrologic variability throughout the basin which is influenced by land surface and subsurface characteristics. It is also necessary to represent variability in pollutant loading, which is highly correlated to land practices. The basis for this distribution was provided by a land-use coverage map of the entire watershed. Two sources of land use data were used in this modeling effort. The primary source of data was the Southern California Association of Governments (SCAG) 2000 land-use dataset that covers Los Angeles County. This dataset was supplemented with land-use data from the 1993 USGS Multi-Resolution Land Characteristic data to fill data gaps. Land-use categories were grouped into seven categories for modeling (Residential, Commercial, Industrial, Open, Agriculture, Water, and Other). Table 24 presents the land use distribution within the watershed for each of the 35 sub-watersheds.

Table 24. Land use distribution in the watershed (square miles).

Watershed	Residential	Commercial	Industrial	Open	Agriculture	Water	Other	Total
1	8.55	0.87	0.52	7.44	0	0	0.32	17.69
2	7.91	0.91	0.28	5.17	0.08	0.04	0.44	14.83
3	4.49	0.6	1.55	15.75	0.2	0	0	22.59
4	4.53	1.23	0.87	5.96	0.4	0.04	0.08	13.12
5	9.86	1.91	2.86	6.52	0	0	0.32	21.47
6	8.67	1.39	0.6	1.67	0.08	0	0	12.41
7	8.11	1.15	3.38	8.23	0.24	0.28	0.12	21.51
8	10.94	1.91	0.44	3.34	0.24	0.12	0.36	17.34
9	17.93	3.58	2.78	4.89	0.48	0.16	0.04	29.86
10	0.76	0	0	33	0.04	0.2	0	34
11	7.04	1.67	1.67	6.88	0.48	0	0.08	17.81
12	7.59	1.59	1.19	0.76	0.16	0	0	11.29
13	4.1	0.36	2.19	120.09	0.12	0.08	0	126.9
14	0.56	0.04	0.24	20.32	0.28	0	0	21.43
15	3.14	0.4	2.62	3.74	0.16	0	0	10.06
16	6.68	1.03	0.95	0.28	0	0	0	8.95
17	5.49	1.59	1.95	0.52	0	0	0	9.54
18	0.95	0.04	0	0.08	0	0	0	1.07
19	9.42	1.55	5.49	12.21	0.12	0	0.2	28.99
20	6.64	1.67	1.59	2.98	0.08	0.04	0.08	13.08
21	9.86	1.35	0.76	13.04	0	0	0.08	25.09
22	2.58	0.28	0.72	4.49	0	0	0	8.07
23	17.5	2.15	2.15	28.39	0.08	0	0.04	50.3
24	10.66	2.07	3.82	7.67	0.08	0	0.28	24.57
25	16.62	6.76	17.5	4.49	0.08	0	0.24	45.69
26	0	0.04	0.04	10.42	0	0	0	10.5
27	9.15	1.55	2.74	15.35	0.56	0.32	0.12	29.78
28	16.06	2.86	1.47	12.29	0.36	0	0	33.04
29	10.74	2.58	1.19	0.99	0	0	0.04	15.55
30	18.37	4.29	2.11	1.99	0.32	0.04	0.12	27.24
31	6.16	1.67	2.35	2.58	0.4	0.2	0	13.36
32	10.3	3.1	5.05	2.27	0.64	0	0.04	21.39
33	23.34	6.16	9.3	1.03	0.08	0.04	0.16	40.12
34	14.04	3.86	3.66	1.63	0.24	0	0.12	23.54
35	6.12	1.87	2.51	1.39	0.04	0.2	0.08	12.21
Percent of Total Area	36.54%	7.68%	10.37%	44.08%	0.72%	0.21%	0.40%	

Weather conditions are the driving force for watershed hydrologic process. The required input includes hourly precipitation and hourly evapo-transpiration for the watershed. Hourly precipitation data were obtained from the National Climatic Data Center (NCDC). After screening the data for location and completeness, hourly rainfall data were obtained from 11 weather stations located in and around the Los Angeles River watershed for October 1998 through December 2001 (Table 25 and Figure 8). Evapo-transpiration rates were calculated from meteorological data for the Los Angeles International Airport.

Table 25. Hourly rainfall data from 11 stations for October 1998 through December 11.

Station #	Description	Elevation (ft)	Latitude	Longitude
CA1194	Burbank Valley Pump PLA	655	34.183	-118.333
CA1682	Chatsworth Reservoir	910	34.225	-118.618
CA3751	Hansen Dam	1087	34.261	-118.385
CA5085	Long Beach AP	31	33.812	-118.146
CA5114	Los Angeles WSO ARPT	100	33.938	-118.406
CA5115	Los Angeles Downtown	185	34.028	-118.296
CA5637	Mill Creek Summit RS	4990	34.387	-118.075
CA7762	San Fernando PH 3	1250	34.317	-118.500
CA7926	Santa Fe Dam	425	34.113	-117.969
CA8092	Sepulveda Dam	680	34.166	-118.473
CA9666	Whittier Narrows Dam	200	34.020	-118.086

The model also requires information on several hydrologic parameters including the degree of imperviousness of the soils, infiltration, groundwater flow and overland flow. The USDA's STATSGO soils data base served as a starting point for designation of infiltration and groundwater flow parameters. This was augmented with information from other modeling applications in the area (i.e., for Santa Monica Bay, Ballona Creek, San Gabriel River). These starting values were refined through the calibration process.

Loading processes for metals (copper, lead, and zinc) for each land use were represented in LSPC through their associations with sediment. The accumulation and washoff of sediments were modeled using the SDMNT module for pervious lands and the SOLIDS module for impervious lands. Sediments washed off by rain are delivered to the stream channel by overland flow. Processes such as transport, deposition and scour of sediments in the stream channels were modeled using the SEDTRN module. These processes depend on sediment characteristics such as particle size distribution (which define settling velocities and the critical shear stresses for deposition and resuspension) and the bottom shear stress predicted by the model.

The model was then used to simulate the in-stream total suspended solids concentrations. Metals associated with these sediments were simulated using the LSPC water quality module. The relationships between sediment and metals (copper, lead and zinc) were parameterized as potency factors developed by SCCWRP (Ackerman et al., 2004). In brief, the potency factor reflects the ratio of total metals loading to sediment loading. Potency factors were defined for copper, lead and zinc for each of seven land-uses categories (agriculture, commercial, industrial, residential, water, other, and open).

5.2.1. Calibration and Validation of the Wet-Weather Model – Flow. Hydrology is the first model component calibrated because estimation of metals loading relies heavily on flow prediction. The hydrology calibration involves a comparison of model results to in-stream flow observations at selected locations. After comparing the results, key hydrologic parameters were adjusted and additional model simulations were performed. This iterative process was repeated until the simulated results closely represented the system and reproduced observed flow patterns and magnitudes.

Key considerations in the hydrology calibration included the overall water balance, the high-flow/low-flow distribution, stormflows, and seasonal variation. At least two criteria for goodness of fit were used for calibration: graphical comparison and the relative error method. Graphical comparisons were useful for judging the results of model calibration. Time-variable plots of observed versus modeled flow provided insight into the model's representation of storm hydrographs, baseflow recession, time distributions, and other pertinent factors often overlooked by statistical comparisons. The model's accuracy was primarily assessed through interpretation of the time-variable plots. The relative error method was used to support the goodness of fit evaluation through a quantitative comparison.

Calibration was focused on flow gages with data for the entire period of record, including a gage draining the headwater subwatersheds (Los Angeles River at Tujunga Avenue) and a gage in a more urban area of the watershed (Rio Hondo above Stuart and Gray Road). After calibrating hydrology at the two locations, a validation of these hydrologic parameters was made through a comparison of model output during the same time period at the other six gages (Table 26). Validation was performed for gages draining single subwatersheds as well as gages on the main stem of the Los Angeles River draining large portions of the watershed. The validation essentially confirmed the applicability of the hydrologic parameters derived during the calibration process. Validation results were assessed in a similar manner to calibration: graphical comparison and the relative error method.

Table 26. Stream gage stations used for calibration and validation of flow data.

Gage Number	Station description	Use
F-45B-R	Rio Hondo above Stuart and Gray Road	Calibration
F-300-R	Los Angeles River at Tujunga Avenue	Calibration
F-285-R	Burbank Western Stormdrain at Riverside Drive	Validation
F-37B-R	Compton Creek near Greenleaf Drive	Validation
F252-R	Verdugo Wash at Estelle Avenue	Validation
F57C-R	Los Angeles River above Arroyo Seco	Validation
F34D-R	Los Angeles River below Firestone Boulevard	Validation
F319-R	Los Angeles River below Wardlow	Validation

Figures 9a and 9b are examples of graphical comparisons used to assess model performance at Los Angeles River below Wardlow River Rd. at the bottom of the watershed. Figure 9a depicts a time-series plot of modeled and observed daily flows. Average monthly model-predicted and observed flows were compared through a regression analysis shown in Figure 9b. The regression line shows a slight under-prediction of measured flows. This under-prediction is due mostly to events occurring in the winter of 1992-1993 and 1994-1995 (Figure 9a). Table 27 reports the results of the analysis performed for the Los Angeles River below Wardlow River Rd. Specifically, volumes were compared under different flow regimes and seasonal periods. For higher flows (highest 10%), the model performs well in predicting storm volumes with an error of –4%. However, for lower flows (lowest 50%) the model is less accurate in predicting flow volumes (–17%) due largely to the inability of the model to simulate variability in point sources and dry-weather urban runoff. A review of these plots also shows that the model is less accurate for low-flow conditions. This is justification for a separate approach for expressing dry-weather allocations and compliance assurance. Hydrology calibration and validation results, including time series plots and relative error tables, are presented for each gage in Appendix II.A.

Table 27. Volumes (acre-feet) and relative error of modeled flows versus observed flow for the Los Angeles River at Wardlow (10/1/1989 – 3/3/1998).

Flows Volumes	Simulated Flow	Observed Flow	Error (%)	Recommended Criteria (%)
Total Stream Volume	394,911	431,200	-9	±10
Highest 10% flows	307,787	320,578	-4	±15
Lowest 50% flows	39,309	46,158	-17	±10
Summer flow volume	20,205	24,797	-23	±30
Fall flow volume	70,661	63,764	10	±30
Winter flow volume	275,206	311,727	-13	±30
Spring flow volume	28,840	30,912	-7	±30

Overall, during model calibration the model predicted storm volumes and storm peaks well. Since the runoff and resulting streamflow are highly dependent on rainfall, occasional storms were over-predicted or under-predicted depending on the spatial variability of the meteorological and gage stations. The validation results also showed a good fit between modeled and observed values, thus confirming the applicability of the calibrated hydrologic parameters to the Los Angeles River watershed.

5.2.2. Calibration and Validation of the Wet-Weather Model - Pollutant Loading. Total suspended solids (TSS) and the potency factors used to determine the relationships between sediment and total metals were developed and calibrated by SCCWRP at specific watersheds in the Los Angeles area. These were validated for use in the Ballona Creek watershed. We did not re-calibrate these parameters for the Los Angeles River. Use of these parameters for the Los Angeles River was validated by comparing model output to in-stream water quality measurements collected during storms. In the validation process, we test the ability of the model to predict 1) the event mean concentration (EMC) at the watershed scale, 2) the EMC at the sub-watershed scale and 3) changes in the instantaneous concentrations over the course of a storm.

To address the first question, we compared EMCs predicted by the model to EMCs calculated from composite measurements made by the LACDPW at the Wardlow Station (1994-2001). The storm EMCs predicted by the model are similar to those calculated from flow-weighted composites (Appendix II.C).

To test the second question, we compared EMCs at four sub-watersheds. EMCs were calculated for Verdugo Wash, Arroyo Seco, Los Angeles River above Arroyo Seco and Los Angeles River at Wardlow based on stormwater sampling that was conducted in 2001. Two to three storms were sampled at each of these subwatersheds. TSS and metals concentrations were measured numerous times (8 to 12) over the course of the individual storms. There is quite a bit of variability in both the predicted and the observed EMCs as evidenced by the 95th-percentile confidence intervals. The predicted EMCs for TSS are generally within the range of the observed EMCs. The predicted EMCs for copper, lead and zinc are generally higher than the observed EMCs. These results presented in Appendix II.B generally indicate that the model is performing well.

To test the third question, we compare the predicted in-stream concentrations associated with each storm at the four sub-watersheds to the instantaneous measurements collected over the course of the storms. The model is not able to adequately represent the variability in concentrations within a storm at the sub-watershed scale. This may be due to limitations in the model to predict flow at the small watershed scale. Perhaps more likely, it reflects limitations in our understanding of the processes associated with sediment washoff and transport. Finally there may be uncertainty associated with the potency factors. However, the general assumption that metals concentrations are associated with suspended solids concentrations appears to be warranted by studies in other watersheds (Schiff and Tiefenthaler, 2001; McPhersson et al. 2004) and the apparent correlation between TSS and the metals concentrations in the observed data.

We conclude that the model is adequate for predicting EMCs but not refined enough for predicting changes in concentration that occur over the course of the storm. The wet-weather model performs better at the watershed level than at the sub-watershed level. In both cases the EMCs predicted by the model are higher than observed. The model will tend to overestimate wet-weather loadings of metals to the river.

6. POLLUTANT ALLOCATION

In this section we develop the loading capacity and allocations for metals in the Los Angeles River. EPA regulations require that a TMDL include waste load allocations (WLAs), which identify the portion of the loading capacity allocated to existing and future point sources (40 CFR 130.2(h)). It is not necessary that every individual point source have a portion of the allocation of pollutant loading capacity. It is necessary, however, to allocate the loading capacity among individual point sources as necessary to meet the water quality objective. As discussed in previous sections, dry-weather and wet-weather conditions are discussed separately.

6.1 Dry-Weather Loading Capacity

The dry-weather loading capacity for the river was developed in the following manner. A reach-specific hardness value was determined to identify the numeric target (see Section 3, Numeric Targets). Numeric targets, expressed as a dissolved metals concentrations (Table 9) were converted to total metals concentrations using CTR default translators (Table 10) and site-specific partition coefficients for copper for the reaches downstream from the Tillman and Glendale POTWs. Next, a critical dry-weather flow was established for specific reaches of the Los Angeles River and listed tributaries. The allowable load for each reach was then derived for each metal by multiplying the hardness adjusted numeric target, expressed as a total metal concentration, by the critical flow assigned to each reach.

Dry-weather flows in the Los Angeles River are influenced highly by the amount of effluent discharge and by the presence of dams on the tributaries. Critical flows for each reach were established from the long-term flow records (1988-2000) generated by stream gages located throughout the watershed and in selected reaches. The median flow was selected as the critical flow. Use of other standard flow cutoffs such as the 7Q10 is inappropriate here because they would result in a critical flow of 0 cfs in most of the tributaries. Use of the median is appropriate in the Los Angeles River since most of the flow is from effluent which results in a relatively stable dry-weather flow condition. We note that the net effect of choosing a lower critical dry weather flow (e.g. 10th percentile) on the load allocation is relatively minor (Table 28). Figure

10 illustrates the 10th, 50th, and 90th percentile flows at Wardlow based on data from 1988 to 2000.

Table 28. A comparison of different total metals load allocations for the entire river (kg/day) based on three critical flows at Wardlow.

Flow (percentile)	Cadmium	Copper	Lead	Zinc
124 cfs (10th)	1.5	6.7	2.3	69
145 cfs (50th)	1.7	7.8	2.6	81
501 cfs (90th)	5.9	26.9	9.3	280

In areas where there were no flow records, we used an area-weighted approach to assign flows to these reaches by multiplying the flow measured at Wardlow by the percent area compromised by a particular reach. Although artificial, we believe this provides a reasonable estimate of the critical flows in each reach. The dry-weather loading capacity for each reach is identified in Table 29.

Table 29. Dry-weather loading capacity for the Los Angeles River and listed tributaries for total metals (kg/day) based on area weighting of median flows at Wardlow (145 cfs).

Los Angeles River	Critical Flow	Cadmium	Copper	Lead	Zinc
LA River Reach 6	7.27	0.11	0.52	0.20	6.74
LA River Reach 5	0.75	0.01	0.05	0.02	0.70
LA River Reach 4	87.68	0.92	4.07	1.41	54.24
LA River Reach 3	25.82	0.30	1.39	0.47	15.66
LA River Reach 2	3.90	0.04	0.20	0.07	2.18
LA River Reach 1	2.61	0.13	0.14	0.05	1.45
Tributaries	**Critical Flow**	**Cadmium**	**Copper**	**Lead**	**Zinc**
Bell Creek	0.55	0.01	0.04	0.01	0.51
Tujunga Wash	0.15	<0.01	0.01	<0.01	0.09
Verdugo Wash	3.34	0.03	0.15	0.05	1.70
Burbank Western Channel	10.96	0.11	0.43	0.16	5.57
Arroyo Seco	0.58	0.01	0.03	0.01	0.33
Rio Hondo	0.50	<0.01	0.01	<0.01	0.16
Compton Creek	0.90	0.01	0.04	0.01	0.51

1. All Tillman flow assigned to Reach 4 for accounting purposes only.
2. Targets for Tujunga Wash, Verdugo Wash, and Arroyo Seco based on hardness in Los Angeles River

6.2 Dry-Weather Allocations

Mass-based waste load allocations are developed for the three POTWs (Tillman, Glendale, and Burbank) and a grouped mass-based waste load allocation is developed for the Los Angeles County MS4, the Long Beach MS4, and the Cal Trans stormwater permittees. Concentration-based waste load allocations are developed for other point sources in the watershed.

Mass-based waste load allocations for Tillman, Los Angeles-Glendale and Burbank POTWs are developed to meet in-stream numeric targets for cadmium, copper, lead and zinc (Table 30). For Tillman, the in-stream targets were based on Reach 5 and 4 of the Los Angeles River. For Glendale, the in-stream targets are based on Reach 3 of the Los Angeles River below the Glendale Plant. For Burbank, the in-stream targets were based on conditions in the Burbank Western Channel downstream of the Burbank WRP. The site-specific translator values for copper were used to adjust the targets for the area downstream of Tillman (Reach 4) and Glendale (Reach 3). The CTR default translators were used for copper in the remaining reaches and for lead and zinc in all of the reaches. The waste load allocations for each plant were calculated by determining the concentration-based permit limits required for each plant to meet the reach-specific water quality targets. Procedures in the SIP were then used to develop 30-day and daily maximum limits. Mass-based allocations were developed by multiplying the 30-day concentration limit by the design flow for each plant and expressing these in terms of kg/day.

Table 30. Proposed waste load allocations for total metals for the three POTWs (concentrations in µg/l) required to meet adjusted TMDL targets.

Facility	Avg period	Cd	Cu	Pb	Zn
Tillman	**30-day**	4 µg/l	18 µg/l	5 µg/l	103 µg/l
	Mass	1.2 kg/d	5.4 kg/d	1.5 kg/d	31.2 kg/d
	Daily	7 µg/l	27 µg/l	12 µg/l	207 µg/l
	Mass	2.1 kg/d	8.1 kg/d	3.6 kg/d	62.7 kg/d
Glendale	**30-day**	4 µg/l	17 µg/l	5 µg/l	187 µg/l
	Mass	0.3 kg/d	1.3 kg/d	0.4 kg/d	14.2 kg/d
	Daily	8 µg/l	31 µg/l	14 µg/l	247 µg/l
	Mass	0.6 kg/d	2.3 kg/d	1.1 kg/d	18.7 kg/d
Burbank2	**30-day**	3 µg/l	12 µg/l	4 µg/l	156 µg/l
	Mass	0.1 kg/d	0.4 kg/d	0.1 kg/d	5.3 kg/d
	Daily	8	26 µg/l	11 µg/l	207 µg/l
	Mass	0.3 kg/d	0.9 kg/d	0.4 kg/d	7.1 kg/d

An alternate approach to setting WLAs for the POTWs would be to allow no net increase in total loadings of the metals. There is some logic to this, given the fact that the waterbody is impaired. Based on our best estimates this would be 0.22 kg/d for cadmium, 3.9 kg/d for copper, 0.5 kg/d for lead and 12.8 kg/d for zinc. This option was not chosen because it would be unreasonable and unnecessary if the POTW effluent meets the concentration based targets at the end-of-pipe.

The POTW loads will ultimately be limited by the total allowable load, which is a function of the critical flow and the in-stream target at the most downstream station in the watershed. The critical flow at Wardlow of 145 cfs is less than the combined design flow of the three POTWs (169 cfs). As POTW flow increases to the design flow, it will take a greater percentage of the total allowable load.

A dry-weather waste load allocation has been developed for municipal stormwater permittees. It is calculated by subtraction after allowing the POTW loads (Table 31). These numbers are based on the loads required to meet the in-stream target at the bottom of the watershed (as defined by Wardlow). The allocations for stormwater require that water quality standards be met within the receiving water for each of the reaches rather than at the end-of-pipe.

Table 31. Remaining dry-weather loading capacity for total metals for the Los Angeles River and listed tributaries (kg/day) to be allocated among stormwater and other permittees.

Los Angeles River	Critical Flow	Cadmium	Copper	Lead	Zinc
LA River Reach 6	7.27	0.11	0.52	0.20	6.74
LA River Reach 5	0.75	0.01	0.05	0.02	0.70
LA River Reach 4	5.18	0.05	0.24	0.08	3.20
LA River Reach 3	4.90	0.06	0.26	0.09	3.08
LA River Reach 2	3.90	0.04	0.20	0.07	2.18
LA River Reach 1	2.61	0.13	0.14	0.05	1.45
Tributaries	**Critical Flow**	**Cadmium**	**Copper**	**Lead**	**Zinc**
Bell Creek	0.55	0.01	0.04	0.01	0.51
Tujunga Wash	0.15	<0.01	0.01	<0.01	0.09
Verdugo Wash	3.34	0.03	0.15	0.05	1.70
Burbank Western Channel	3.30	0.04	0.18	0.06	1.93
Arroyo Seco	0.58	0.01	0.03	0.01	0.33
Rio Hondo	0.50	<0.01	0.01	<0.01	0.16
Compton Creek	0.90	0.01	0.04	0.01	0.51

Concentration-based waste load allocations have been developed for the minor NPDES dischargers, NPDES discharges covered under a general permit, and the major NPDES discharges excluding Tillman, LA-Glendale, and Burbank POTWs. This was done since there is insufficient flow information from these discharges to develop individual mass-based waste load allocations. Similarly, concentration-based limits are being placed on dry-weather flows associated with the general industrial stormwater permits and the general construction stormwater permits. Concentration-based waste load allocations, based on reach-specific dry-weather numeric targets, expressed as total metals, to be applied to these permits are provided in Table 32.

Table 32. Concentration-based dry-weather waste load allocations (adjusted for hardness by reach) in terms of total metals concentrations (µg/L) for all NPDES discharges, excluding Tillman,LA-Glendale, and Burbank POTWs and the municipal and Caltrans stormwater permittees.

River Reach	Cd	Cu	Pb	Zn
LA Reach 5	6.6	30	13.9	387
LA Reach 4 and Tujunga Wash	4.6	21*	8.4	211
LA Reach 3 Above LAG WRP	5.1	23	9.6	244
LA Reach 3 and Arroyo Seco	5.1	25*	9.5	253
Burbank (above Burbank WTP)	5.7	26	11.3	280
Burbank (below Burbank WTP)	4.4	19	7.7	212
LA Reach 2	5.0	22	9.2	234
LA Reach 1	5.1	23	9.6	233
Compton Creek	4.4	19	7.6	238
Rio Hondo	3.1	13	4.7	131
Monrovia Canyon Creek	4.1	18	7.1	199

*Site-specific copper translators were used to adjust the targets downstream of Tillman and Glendale.

We have not developed dry-weather load allocation for non-point sources in this TMDL.
We did not develop a specific load allocation for natural background sources because most of the land area in the watershed is covered under the stormwater permit. The exception is the area of the Angeles National Forest and the open areas of the Santa Monica Mountains. No allocation was given to these areas because dry-weather loads from these areas are thought to be insignificant. Little if any natural flow from these areas reaches the listed areas of the Los Angeles River watershed and the background metals concentrations associated with these flows are expected to be low. We did not develop allocations for atmospheric deposition because the loadings associated with direct deposition are insignificant relative to the total allowable load (less than 0.05%)

6.3 Wet-Weather Loading Capacity

During wet weather, the allowable load is a function of the volume of water in the river. Given the variability in wet-weather flows, the concept of a single critical flow is not appropriate. Instead, we apply load-duration curves to establish the wet-weather loading capacity. In brief, a load-duration curve is developed by multiplying the wet-weather flows by the in-stream numeric target. The result is a curve which identifies the flow-weighted allowance for a given storm volume. A load-duration curve for the Los Angeles River was established using the long-term flow record from the LACDPW station at Wardlow.

The LSPC model was used to simulate storm volumes and associated metals loads over the 12-year period which represented various storm conditions. A single storm was defined as a day that rainfall occurs, plus all consecutive days that satisfy the following criteria: (1) flow is above baseflow (50^{th} percentile flow or approximately 145 cfs at the mouth of the Los Angeles River- see figure 10), and (2) rainfall occurs following a previous day of no rainfall. We then aggregated storm volumes, storm loads, and accumulated rainfall (in inches) over each storm's period. Loading capacities for each storm were then calculated by multiplying the storm volume by the appropriate numeric water quality target.

These metals loading capacities were ranked by the amount of rainfall that occurred over the storm period. This wet-weather TMDL is based on total metals concentrations, so for those metals with criteria expressed as dissolved metals concentrations (Table 11), targets were converted to total metals concentrations using appropriate translators. For stormwater, translators for copper, lead and zinc were based on the regressions in Table 12. The CTR default translator was used for cadmium. The metals loading capacities and model-predicted historic loads for copper, lead and zinc are plotted in load-duration curves provided in Figures 11a-11c. For these figures, the loading capacity is a black line, the model-predicted historical loads below the loading capacity are shaded with dashes and the model-predicted historical loads above the loading capacity are shaded with dots.

6.4 Wet-Weather Allocations

Mass-based waste load allocations were developed for the three POTWs (Tillman, Glendale, and Burbank) and a grouped waste load allocation was developed for the municipal stormwater permittees. Allocations are developed using the load-duration curve concept. The total wet-weather waste load allocation for wet weather varies by storm. Given this variability in stormwater flows, we found no justification for selecting a particular sized storm as the critical condition. The load-duration curves demonstrate that exceedances occur most frequently during large storms (i.e., in excess of 0.5 inches). Therefore, these high magnitude storms represent the critical condition. Because the model tends to overestimate loads, actual reductions required to meet the waste load allocations are likely less than predicted by the load-duration curves.

For the Tillman, LA-Glendale, and Burbank POTWs, the wet-weather load allocation is flow-weighted. The concentration-based targets apply but the mass discharge limitation will not apply when in-stream flows exceed the design capacity of the treatment plants. During wet weather, the POTWs will retain the waste load allocations assigned for dry weather. However, the POTW loads represent an insignificant fraction of the total waste load allocation during large storms. Therefore, the major waste load allocation and required reductions are assigned to the MS4 system and the NPDES-regulated municipal stormwater discharges.

EPA allows allocations for NPDES-regulated municipal stormwater discharges from multiple point sources to be expressed as a single categorical waste load allocation when data and information are insufficient to assign each source or outfall individual allocations. We recognize that these municipal stormwater allocations may be fairly rudimentary because of data limitations and variability in the system. Waste load allocations for copper, lead, and zinc for the municipal stormwater discharges are presented in figures 11a through 11c. The loading capacity is shown as a black line and the shaded area above the curve represents the required reductions in model-predicted historical loads needed to meet the allocation. Wet-weather historical loadings for cadmium were not modeled in this TMDL. Our review indicated that there was little evidence of wet-weather exceedances and that estimates of wet-weather loadings (LACDPW and SCCWRP) were well below the allowable load. The loading capacity for cadmium is presented in figure 11d.

The minor NPDES permittees, construction stormwater permittees and industrial stormwater permittees, most of which discharge to the MS4 system, are assigned a concentration-based waste load allocation equal to reach-specific numeric targets, expressed as total metals concentrations (Table 33.) Similarly, NPDES discharges covered under a general permit and the major NPDES permittees excluding Tillman, LA-Glendale, and Burbank POTWs are assigned concentration-based waste load allocations. Based on a review of industrial stormwater monitoring data, it appears that substantial reductions will be required at several industrial facilities to meet the applicable CTR values. These reductions will translate to reductions in the existing load to the MS4 system. However, the magnitude of this reduction cannot be quantified based on existing available data.

Table 33. Concentration-based wet -weather waste load allocations for total metals (µg/L). Values based on median hardness value at Wardlow (80 mg/L as $CaCO_3$).

Cadmium	Copper	Lead	Zinc
3.2	17	62	159

As with the dry-weather condition, no wet-weather load allocations were developed for background or atmospheric deposition. The rationale is similar as for the dry-weather allocations. Most of the area in the watershed is covered under the stormwater permit. The areas within the National Park or State Park system that are not covered under the stormwater permit are unlikely to contribute significantly to the overall load. The wet-weather loadings from open space are also believed to be minor (Table 34). We do not believe that it is necessary or desirable to develop load allocations for metals from these areas. The loadings associated with indirect deposition are addressed through the stormwater waste load allocations.

6.5 Margin of Safety

The statute and regulations require that a TMDL include a margin of safety to account for any lack of knowledge concerning the relationships between effluent limitations and water quality. A margin of safety is appropriate for each TMDL because there is significant uncertainty in the analysis of pollutant loads and effects on water quality. There is an implicit margin of safety that stems from two conservative assumptions: (1) the use of conservative values for the translation from total to the dissolved fraction during the dry and wet periods, and (2) the use of a dry-weather critical flow which is less than the design flow of the three treatment plants. In addition, the wet-weather metals loadings predicted by the model tend to overestimate the actual loadings. Therefore, the estimated percent reduction necessary to meet the waste load allocation is conservative.

7. IMPLEMENTATION

In this section, we describe the implementation procedures that will be used to provide reasonable assurances that water quality standards will be met. As with the other sections the implementation will vary between dry and wet periods.

The WLAs established for the three major POTWs in this TMDL will be implemented through NPDES permit limits. The renewal of the NPDES permits for the three major POTWs is tentatively scheduled for July 2005. The three POTWs will have permit limits designed to meet the water quality targets established in this TMDL and maintain water quality standards in the Los Angeles River. Proposed permit limits have been developed using the guidelines in the SIP (Table 30). These limits take into account the variability in the effluent data and the frequency of monitoring. During wet weather when the inflow to the treatment plants exceeds the design capacity, the mass-based limit will not apply.

The concentration-based waste load allocations for industrial and construction stormwater discharges, minor NPDES discharges, NPDES discharges covered under a general permit and major NPDES discharges excluding the Tillman, LA-Glendale, and Burbank POTWs will be implemented through NPDES permit limits. Reach-specific dry-weather waste load allocations are described in Table 32 and wet-weather waste load allocations are described in Table 33. Likewise, the concentration-based waste load allocations that apply to the Tillman, LA-Glendale and Burbank POTWs when flow exceeds their design capacities (Table 33) will also be implemented through their respective NPDES permits. Monitoring requirements will be placed on these discharges as appropriate.

A grouped mass-based waste load allocation has been developed for the MS4 system. EPA regulation allows allocations for NPDES-regulated stormwater discharges from multiple point sources to be expressed as a single categorical waste load allocation when the data and information are insufficient to assign each source or outfall individual WLAs. The grouped allocation will apply to all NPDES-regulated municipal stormwater discharges in the Los

Angeles watershed including the Los Angeles County MS4 permit, the City of Long Beach MS4 permit, and the Caltrans stormwater permit.

EPA policy requires that the waste load allocations for stormwater be expressed in numeric form. For the dry-weather condition, mass-based waste load allocations (Table 31) will be incorporated into the permits of the NPDES-regulated municipal stormwater discharges. For the wet-weather, the municipal stormwater waste load allocations are expressed as load capacity curves presented in figures 11a-11e. We envision that these will be allocated to each jurisdiction on the drainage to each reach.

Each municipality and permittee will be required to meet the waste load allocations, and are not necessarily given a specific allocation for their jurisdiction or land uses under their jurisdiction. Therefore, the focus of compliance should be on developed areas where the contribution of metals is highest and areas where activities occur that contribute significant loading of metals (e.g., high-density residential, industrial areas and highways). Flexibility will be allowed in determining how to reduce metals as long as the waste load allocations are achieved. The information provided in Table 34 should help stormwater permittees identify areas of high pollutant loading and may be used to target BMPs.

Table 34. Land use contributions to total metal loads from surface runoff from the Los Angeles River watershed.

Land Use	Copper	Lead	Zinc
Agriculture	0.5%	0.2%	0.5%
Commercial	13.4%	18.6%	18.2%
Industrial	11.2%	9.1%	19.9%
Mixed Urban	0.7%	0.3%	0.6%
Residential	71.5%	71.1%	59.3%
Open Space	2.8%	0.7%	1.6%

To achieve the necessary reductions to meet the waste load allocations, permittees will need to balance short-term capital investments directed to addressing this and other TMDLs in the Los Angeles River watershed with long-term planning activities for stormwater management in the region as a whole. It should be emphasized that the potential implementation strategies discussed below may contribute to the implementation of other TMDLs for the Los Angeles River watershed. In addition, implementation of other TMDLs in the Los Angeles River watershed may contribute to the implementation of this TMDL.

7.1 Integrated Resources Plan

The Regional Board supports in concept an integrated water resources approach to improving water quality during wet weather, such as the City of Los Angeles' Integrated Plan for the Wastewater Program (IPWP). An integrated water resources approach takes a holistic view of regional water resources management by integrating planning for future wastewater, stormwater, recycled water, and potable water needs and systems, and focusing on beneficial re-use of stormwater at multiple points throughout a watershed to preserve local groundwater resources and reduce the need for imported water where feasible. The City's IPWP is intended to meet the wastewater and water resource management needs for year 2020.

The Integrated Resources Plan (IRP) is Phase 2 of the IPWP. The IRP is a City-wide strategy developed by the City of Los Angeles and does not specifically focus on the Los Angeles River watershed. The goal of the plan is to capture and beneficially use 50% of the annual average wet-weather urban runoff. However, it is not known what portion of this runoff will be in the Los Angeles River Watershed. Furthermore, capture and beneficial use of 50% of the annual average wet-weather urban runoff may not achieve the waste load allocations in this TMDL during very wet years. The implementation strategy proposed below could be designed to achieve the TMDL requirements, while remaining consistent with the goals of the City's IPWP and addressing any shortfall of the IRP in achieving implementation with this TMDL.

One component of the IRP is a Runoff Management Plan, which could provide a framework for implementing runoff management practices to meet the IRP goals and address protection of public health and the environment. The Runoff Management Plan as described in the IRP will include consideration of structural Best Management Practices (BMPs) to achieve reduction of pollutant loadings to receiving waters. Urban runoff can be treated at strategic locations throughout the watershed or subwatersheds.

7.2 Potential Implementation Strategies

The implementation strategy selected will need to address the different sources of metals loading during dry and wet weather. During dry weather, metals loading are predominately in the dissolved phase as demonstrated by the default CTR conversion factors. During wet weather, the metals loading are predominately bound to sediment, which are transported with storm runoff. During rain events, partitioning between particulate and dissolved metals often does not reach equilibrium. Municipalities may employ a variety of implementation strategies to meet the required WLAs such as non-structural and structural BMPs, and/or diversion and treatment. Specific projects, which may have a significant environmental impact, would be subject to an environmental review. The lead agency for subsequent projects would be obligated to mitigate any impacts they identify, for example by mitigating potential flooding impacts by designing the BMPs with adequate margins of safety.

7.2.1 Non-structural BMPs. The non-structural BMPs are based on the premise that specific land uses or critical sources can be targeted to achieve the TMDL waste load allocations. Non-structural BMPs provide several advantages over structural BMPs. Non-structural BMPs can typically be implemented in a relatively short period of time. The capital investment required to implement non-structural BMPs is generally less than for structural BMPs. However, the labor costs associated with non-structural BMPs may be higher. Therefore, in the long-term, the non-structural BMPs may be more costly. Examples of non-structural controls include more frequent and appropriately timed storm drain catch basin cleanings, improved street cleaning by upgrading to vacuum type sweepers and educating industries of good housekeeping practices. Since dry-weather exceedances appear to be episodic, the permittees are encouraged to initially concentrate on source reduction strategies including detection and elimination of illicit discharges, reduction of dry-weather nuisance flows, and increased inspection of industrial facilities. In addition, improved enforcement of BMPs for construction sites and improved detection and elimination of illicit connections to the storm drain system may result in significant reductions in discharges of metal pollutants to the Los Angeles River.

A known source of copper loading is from brake pads. The permittees could sponsor legislative actions with state and federal agencies to pursue the development of alternative materials for brake pads. The use of alternative materials for brake pads would help to reduce the discharge of copper in all watersheds. Just as the phase out of leaded gasoline resulted in the gradual decline of lead concentrations in the environment, a phase out of copper brake linings would also be expected to reduce the amount of copper in stormwater runoff.

7.2.2 Structural BMPs. The structural BMPs are based on the premise that specific land uses, critical sources, or specific periods of a storm event can be targeted to achieve the TMDL waste load allocations. Structural BMPs may include placement of stormwater treatment devices specifically designed to reduce metals loading, such as infiltration trenches or filters, at critical points in the stormwater conveyance system. During storm events, when flow rates are high, these types of filters may require surge control, such as an underground storage vault or detention basin. If these filters are placed in series with the gross solids removal systems being installed to meet the Trash TMDL, then these filters will operate more efficiently and will require less maintenance. These structural solutions may be designed to capture the runoff from a specific storm period such as the first 0.1 or 0.5 inches of rain.

7.2.3 Diversion and Treatment. The diversion and treatment strategy includes the installation of facilities to provide capture and storage of dry and/or wet-weather runoff and diversion of the stored runoff to a wastewater collection system for treatment. A small, dedicated runoff treatment facility or alternative BMPs may be implemented to meet the TMDL requirements.

The volume of flow requiring storage and treatment would have to be estimated in order to size the storage facilities, estimate diversion flow rates, and determine the collection system and treatment capacities needed to accommodate these diverted flows. These storage and diversion facilities will be sized to accommodate the requisite storage volumes and appropriate rates of diversion to the collection system to avoid overflows. Wet-weather flows beyond the capacities of these facilities will be bypassed. However, a portion of these larger storm events will still be captured and treated, thereby eliminating the metals loading of small storms and reducing those of larger storms. Overflows from these systems could be routed through structural BMPs designed to remove sediment for further reduction of metal loads.

To assist responsible jurisdictions and agencies in determining the optimal volume of flow to be diverted, analyses were performed to assess relative improvements and benefits associated with capture of storm volumes. The capture of storm volumes reduces the associated metals loads, and therefore reduces the likelihood of exceedances of loading capacities of the receiving waters. These analyses were based primarily on conceptual assumptions and analyses of model results for guidance in future planning. To begin quantifying loading reductions, the results of the wet-weather model were re-analyzed with respect to size of storm flow. This was done by first developing a relationship between rainfall and storm volume for storms greater than 0.1 inch (Figure 12). We then used the regression to assess the effect of storm capture to reduce the associated metals loads, and therefore number of exceedances. The model suggests that the number of instances where model-predicted historical loads exceed the loading capacity can be halved through the capture of a 0.5 inch storm. These results are provided as guidance only and are not meant to imply that structural means are necessary to meet the load reductions in this TMDL. Indeed, we believe that BMPs that result in source reductions rather than in-stream storm load reductions should be encouraged.

Additional studies that evaluate the effect of short duration rainfall intensity (i.e., one-year, one-hour rainfall event) on the mobilization and transport of metals are encouraged and would be useful in designing the flow through design capacity of in-line BMPs.

The administrative record and the fact sheets for the Los Angeles MS4 permit, the Long Beach MS4 permit, and the Caltrans stormwater permit must provide reasonable assurance that the BMPs selected will be sufficient to implement the waste load allocations in the TMDL. We expect that reductions to be achieved by each BMP will be documented and that sufficient monitoring be put in place to verify that the desired reductions are achieved. The permits should also provide a mechanism to make adjustments to the required BMPs as necessary to ensure their adequate performance. If non-structural BMPs alone adequately implement the waste load allocations then additional controls are not necessary. Alternatively, if the non-structural BMPs selected prove to be inadequate then structural BMPs or additional controls may be imposed.

7.3 Implementation Schedule

The proposed implementation schedule shall consist of a phased approach, with compliance to be achieved in prescribed percentages of the watershed, with total compliance to be achieved within 15 years, as summarized in Table 35. The dry-weather compliance schedule is more accelerated because the dry-weather exceedances occur infrequently and major structural BMPs are not anticipated. The municipal stormwater permittees are encouraged to work together to identify areas to be addressed first.

The Regional Board intends to reconsider this TMDL in six years after the effective date of the TMDL to re-evaluate the waste load allocations based on the additional data obtained from special studies. Until the TMDL is revised, the waste load allocations will remain as presented in Tables 30, 31, 32, and 33 and figures 11a – 11d. The Regional Board does not intend to revise the waste load allocations until reductions have been achieved. Revising the TMDL will not create a conflict, since full compliance with the dry-weather WLAs is not required until ten years after the effective date and full compliance with the wet-weather WLAs is not required until 15-years after the effective date of the TMDL.

Table 35. Implementation Schedule.

Date	Action
Effective date of TMDL	Apply wet- and dry-weather waste load allocations to the Tillman, LA-Glendale, and Burbank POTWs, other major NPDES discharges, general NPDES discharges, minor NPDES discharges and industrial and construction stormwater NPDES discharges. Waste load allocations will be implemented through NPDES permit limits at the time of their renewal.
120 days after the effective date of the TMDL	The MS4 and Caltrans stormwater NPDES permittees must submit a coordinated monitoring plan, to be approved by the Executive Officer, which includes both compliance assessment monitoring and ambient monitoring. Once the coordinated monitoring plan is approved by the Executive Officer ambient monitoring shall commence.
12 months after effective date of TMDL (Draft Report) 16 months after effective date of TMDL (Final Report)	The MS4 and Caltrans stormwater NPDES permittees shall provide a written report to the Regional Board outlining the drainage areas to be addressed and how these areas will achieve compliance with the waste load allocations. The report shall include implementation methods, an implementation schedule, proposed milestones, and any applicable revisions to the compliance monitoring plan.
4 years after effective date of the TMDL	Responsible jurisdictions and agencies shall provide to the Regional Board results of the special studies conducted as part of the ambient monitoring program.
6 years after effective date of the TMDLs	The Regional Board shall reconsider this TMDL to re-evaluate the waste load allocations.
6 years after effective date of the TMDL	50% of the total drainage area shall achieve compliance with the dry-weather waste load allocations and 25% of the total drainage area will achieve compliance with the wet-weather waste load allocations assigned to the MS4 system.
8 years after effective date of the TMDL	75% of the total drainage area shall achieve compliance with the dry-weather WLAs assigned to the MS4 system.
10 years after effective date of the TMDL	100% of the total drainage area shall achieve compliance with the dry-weather WLAs and 50% of the total drainage area will achieve compliance with the wet-weather WLAs assigned to the MS4 system.
15 years after effective date of the TMDL	100% of the total drainage area shall achieve compliance with both the dry-weather and wet-weather WLAs assigned to the MS4 system.

7.4 Cost Analysis

This section takes into account a reasonable range of economic factors in estimating potential costs associated with this TMDL in fulfillment of the applicable provisions of the California Environmental Quality Act (Public Resources Code Section 21159.)

This cost analysis focuses on compliance with the grouped waste load allocation by the NPDES-regulated stormwater permittees in the urbanized portion of the watershed[1]. An evaluation of the costs of implementing this TMDL amounts to evaluating the costs of preventing metals and sediment from entering storm drains and/or reaching the river. Most permittees would likely implement a combination of the structural and non-structural BMPs to achieve compliance with their waste load allocations. This analysis considers a potential strategy combining structural and non-structural BMPs through a phased implementation approach and estimates the costs for this strategy. It will also be important to document reductions in metals loading already being achieved via BMPs currently employed under the Trash TMDL.

In addition to achieving compliance with this TMDL, such a strategy could be used to achieve compliance with the Los Angeles River Trash TMDL, now in its first year of implementation, as well as the upcoming Los Angeles River Bacteria TMDL. Therefore, this cost analysis reflects the potential costs of compliance with multiple TMDLs based on likely implementation scenarios.

7.2.1 Cost estimate based on a phased implementation approach. Under a phased implementation approach, it is assumed that compliance with the grouped waste load allocation could be achieved in 30% of the urbanized portion of the watershed through an integrated resources plan. Compliance in another 30% of the urbanized portion of the watershed could be achieved through various iterations of non-structural BMPs. Compliance with the remaining 40% of the urbanized portion of the watershed could be achieved through structural BMPs.

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[1] The Los Angeles River Watershed is 834 square miles. The Angeles National Forest comprises 250 square miles of the watershed. The remaining 584 square miles of the watershed is comprised of incorporated cities or unincorporated portions of Los Angeles County. Open space comprises 112 square miles and water comprises 10 square miles of the incorporated cities and unincorporated County areas. The remaining 462 square miles can be considered the urbanized portion of the watershed for the purposes of this TMDL.

The first step of a potential phased implementation approach would include the implementation of non-structural BMPs by the permittees, such as increasing the frequency and efficiency of street sweeping. In their National Menu of Best Management Practices for Stormwater - Phase II, U.S. EPA reports that conventional mechanical street sweepers can reduce non-point source pollution by 5-30% (USEPA, 1999a.) The removal efficiencies of sediment for conventional sweepers are dependent on the size of particles. Conventional sweepers, including mechanical broom sweepers and vacuum-assisted wet sweepers, have removal efficiencies of approximately 15 to 50% for particles less than 500 micrometers and up to approximately 65% for larger particles (Walker and Wong, 1999). U.S. EPA reports that vacuum-assisted dry street sweeping can remove significantly more pollution, including fine sediment and metals, before they are mobilized by rainwater. U.S. EPA reports a 50 - 88 percent overall reduction in annual sediment loading for residential areas by vacuum-assisted dry street sweepers. Sutherland and Jelen (1997) showed a total removal efficiency of 70% for fine particles and up to 96% for larger particles by vacuum–assisted dry sweepers (also known as small-micron surface sweepers.) Upgrading to vacuum-assisted dry sweeping would translate to a significant reduction of metals in the particulate phase.

In their 1999 Preliminary Data Summary of Urban Stormwater Best Management Practices, U.S. EPA estimated cost data for both standard mechanical and vacuum-assisted dry sweepers as shown in Table 36.

Table 36. Estimated costs for two types of street sweepers.

Sweeper Type	Life (Years)	Purchase Price ($)	O&M Cost ($/curb mile)
Mechanical	5	75,000	30
Vacuum-assisted	8	150,000	15

Source: USEPA, 1999b

Table 36 illustrates that while the purchase price of vacuum-assisted dry sweepers is higher, the operation and maintenance costs are lower than for standard sweepers. Based on this information, U.S. EPA determined the total annualized cost of operating street sweepers per curb mile, for a variety of frequencies (in Table 37). In their estimates, U.S. EPA assumed that one sweeper serves 8,160 curb miles during a year and assumed an annual interest rate of 8 percent

(USEPA, 1999b). According to Table 37, permittees would save money in the long-term by switching to vacuum-assisted dry sweepers.

Table 37 Annualized sweeper costs, including purchase price and operation and maintenance costs ($/curb mile/year).

Sweeper Type	Sweeping Frequency					
	Weekly	Bi-weekly	Monthly	Quarterly	Twice per year	Annually
Mechanical	1,680	840	388	129	65	32
Vacuum-Assisted	946	473	218	73	36	18

Under a phased implementation approach, the permittees could monitor compliance using flow-weighted composite sampling of runoff throughout representative storms to determine the effectiveness of this first step of implementing non-structural BMPs. If monitoring showed non-compliance, permittees could adapt their approach by increasing frequency of street sweeping or incorporating other non-structural BMPs.

If compliance could still not be achieved through non-structural BMPs, permittees could incorporate structural BMPs. Two potential structural BMPs were analyzed in this cost analysis:

1. Infiltration trenches
2. Sand filters

Both approaches can be designed to capture and treat 0.5 to 1 inches of runoff. When flow exceeds the design capacity of each device, untreated runoff is allowed to bypass the device and enter storm drains or the river.

Both infiltration trenches and sand filters must be used in conjunction with some type of pretreatment device such as a biofiltration strip or gross solids removal device to remove sediment and trash in order to increase their efficiency and service life. This combination could be used to achieve compliance with both the Los Angeles River Trash TMDL and the Metals TMDL. The Trash TMDL provided a cost estimate of gross solids removal devices, including structural vortex separation systems and end of pipe nets. This analysis provides an estimate of the additional costs associated with installing sand filters or infiltration trenches.

In addition, both infiltration trenches and sand filters are efficient in removing bacteria and could be used to achieve compliance with the upcoming bacteria TMDL. U.S. EPA reports that sand filters have a 76% removal rate and infiltration trenches have a 90% removal rate for fecal coliform. (U.S. EPA National Menu of Best Management Practices for Stormwater - Phase II EPA 832-F-99-007. 1999)

In this cost analysis, it was assumed that 20% of the watershed would be treated by infiltration trenches and 20% of the watershed would be treated by sand filters. Costs were estimated using data provided by U.S. EPA in their 1999 National Menu of Best Management Practices for Stormwater - Phase II and the Federal Highway Administration (FHWA) in their Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. Where costs were reported as ranges, the highest reported cost was assumed. These costs were then compared to costs determined by Caltrans in their BMP Retrofit Pilot Program (2004). Analysis of costs based on EPA, FHWA estimates and those reported by Caltrans are included in Appendix III.

Infiltration trenches. Infiltration trenches store and slowly filter runoff through the bottom of rock-filled trenches and then through the soil. Infiltration trenches can be designed to treat any amount of runoff, but are ideal for treating small urban drainage areas less than five to ten acres. Soils and topography are limiting factors in design and siting, as soils must have high percolation rates and groundwater must be of adequate depth. Infiltration trenches are reported to achieve 75 to 90% suspended solids removal and 75-90% metals removal by U.S. EPA and FHWA. In their BMP Retrofit Pilot Program, Caltrans assumed that constituent removal was 100 percent for storm events less than the design storm, because all runoff would be infiltrated.

Table 38 presents estimated costs for infiltration trenches designed to treat 0.5 inches of runoff over a five-acre drainage area with a runoff coefficient equal to one. Staff determined that 11,827 devices, designed to treat five acres each, would be required to treat 20% of the urbanized portion of the watershed.

Table 38. Estimated costs for infiltration trenches.

	Construction Costs ($ million)	Maintenance Costs ($ million/year)
Based on EPA estimate (Brown and Schueler, 1997, SWRPC, 1991)	538	108
Based on FHWA estimate (Young et al., 1996, Schueler, 1987)	514	Not reported

Sand Filters. Sand filters work by a combination of sedimentation and filtration. Runoff is temporarily stored in a pretreatment chamber or sedimentation basin, then flows by gravity or is pumped into a sand filter chamber. The filtered runoff is then discharged to a storm drain or natural channel. The costs of two types of sand filters were analyzed: 1) the Delaware sand filter, which is installed underground and suited to treat drainage areas of approximately one acre and 2) the Austin sand filter, which is installed at-grade and suited to larger drainage areas up to 50 acres.

U.S. EPA estimated a 70% removal of total suspended solids and 45% removal of lead and zinc for both types of sand filters. FHWA reported high sediment, zinc and lead removal, but low copper removal for Austin sand filters and high sediment and moderate to high metals removal for Delaware sand filters. Caltrans reported a 50% reduction in total copper, a 7% reduction in dissolved copper, an 87% reduction in total lead, a 40% reduction in dissolved lead, an 80% reduction in total zinc and a 61% reduction in dissolved zinc by the Austin sand filters they tested. Caltrans reported a 66% reduction in total copper, a 40% reduction in dissolved copper, an 85% reduction in total lead, a 31% reduction in dissolved lead, a 92% reduction in total zinc and a 94% reduction in dissolved zinc by the Delaware sand filter they tested.

U.S. EPA and FHWA reported costs per acre for 0.5 inches of runoff. Total costs were calculated by multiplying the per-acre cost by the total acreage of the urbanized portion of the watershed not addressed through an integrated resources plan or non-structural BMPs. Estimated costs are presented in Table 39. There are significant economies of scale for Austin filters. U.S. EPA reported that costs per acre decrease with increasing drainage area. FHWA reported two separate costs based on drainage area served. Economies of scale are not a factor for Delaware filters, as they are limited to drainage areas of about one acre.

Table 39. Estimated costs for Austin and Delaware sand filters.

	Austin Sand Filter Construction Costs ($ million)	Austin Sand Filter Maintenance Costs ($ million/year)	Delaware Sand Filter Construction Costs ($ million)	Delaware Sand Filter Maintenance Costs ($ million/year)
Based on U.S. EPA estimate (1999)	547	27	325	16
Based on FHWA estimate* (Schueler, 1994)	100	Not reported	414	Not reported

*FHWA cost estimate for Austin filters calculated assuming a drainage area greater than five acres. Total Costs would be $473 million for devices designed for a drainage area of less than two acres.

Based on the phased implementation approach, and some assumptions about the efficacy of each stage of the approach, the cost analysis arrived at the total costs for compliance with the Metals TMDL as shown in Table 40. The total costs do not include the cost savings associated with switching to vacuum-assisted street sweepers. As stated previously, the costs associated with this approach could be applied towards the cost of compliance with both the Metals TMDL and Bacteria TMDL.

Table 40. Total estimated costs of phased implementation approach.

	Total Construction ($ million)	Total Maintenance ($million/year)
Based on U.S. EPA estimate (1999)	1410	151
Based on FHWA estimate* (Schueler, 1994)	1028	Not reported

7.2.2 Comparison of costs estimates with Caltrans reported costs. Estimated costs for structural BMPs were compared to costs reported by Caltrans in their BMP Retrofit Pilot Program (Caltrans, 2004). Caltrans sited five Austin sand filters and one Delaware sand filter as part of their study. The five Austin sand filters served an average area of two acres and the Delaware sand filter served an area of 0.7 acres. Caltrans sited two infiltration trench/biofiltration strip combinations as part of their study. Each trench and biofiltration strip used in combination served an area of 1.7 acres. Based on these drainage areas, the average adjusted cost of the Austin sand filters in the Caltrans study was $156,600 per acre, the adjusted cost of the Delaware filter was $310,455 per acre and the average adjusted cost of the infiltration trench/biofiltration strips was $85,495 per acre. These costs are approximately an order of magnitude greater than the costs determined using estimates provided by U.S. EPA and FHWA.

The Caltrans study was subject to a third party review, conducted by Holmes & Narver, Inc. and Glenrose Engineering (Caltrans, 2001.) The review compared adjusted Caltrans costs with costs of implementing BMPs by other state transportation agencies and public entities. The adjusted costs exclude costs associated with the unique pilot program and ancillary costs such as improvements to access roads, landscaping or erosion control, and non-BMP related facilities. For the comparison, all costs were adjusted for differences in regional economies. The third party review determined that the median costs reported by Caltrans were higher than the median costs reported by the other agencies for almost every BMP considered, including sand filters and infiltration BMPs. The review attributed the higher Caltrans costs to the small scale and accelerated nature of the pilot program. The third party review then gave recommendations for construction cost reductions based on input from other state agencies. These included simplifying design and material components, combining retrofit work with ongoing construction projects, changing methods used to select and work with construction contractors, allowing for a longer planing horizon, constructing a larger number of BMPs at once, and implementing BMPs over a larger drainage area.

8. MONITORING

There are three objectives of the monitoring program. The first is to collect data (e.g., hardness, flow, and background concentrations) to evaluate the uncertainties and assumptions made in development of the TMDL. The second is to collect data to assess compliance with the waste load allocations. The third is to collect data to evaluate potential management scenarios. To achieve these objectives, the monitoring program for the TMDL consists of three components: (1) ambient monitoring, (2) compliance assessment monitoring and (3) special studies.

8.1 Ambient Monitoring

An ambient monitoring program is required to assess water quality throughout the Los Angeles River and its tributaries. The MS4 and Caltrans stormwater NPDES permittees are jointly responsible for implementing the ambient monitoring program. The responsible agencies shall sample for total metals, dissolved metals, and hardness once per month at each ambient monitoring location. There are eight proposed ambient monitoring points on the Los Angeles River to reflect the reaches and the monitoring stations (Table 41). These stations correspond to the City of Los Angeles Watershed Monitoring Stations. The City currently samples for metals at these eight monitoring stations once per month. In early 2004, the City began sampling for hardness with the same frequency. The City plans to extend their program to include metals sampling of the tributaries in the future.

Table 41. Ambient Monitoring Points.

Ambient Monitoring Points	Reaches
White Oak	LA River 6, Aliso Creek, McCoy, Aliso, Bull, Bell
Sepulveda Avenue	LA River 5, Bull Creek
Tujunga Avenue	LA River 4, Tujunga Wash
Colorado Avenue	LA River 3, Burbank Western Channel, Verdugo Wash
Figueroa	LA River 3, Arroyo Seco
Washington	LA River 2
Rosecrans	LA River 2, Rio Hondo (gage just above Rio Hondo)
Willow	LA River 1, Compton Creek (gage at Wardlow)

8.2 Compliance Assessment Monitoring

The compliance assessment monitoring requirements for TMDL implementation will be specified in NPDES permits for the Tillman, LA-Glendale, and Burbank POTWs and the MS4 and Caltrans stormwater NPDES permits. The permits should specify the monitoring necessary to determine if the expected load reductions are achieved. This is particularly critical for the stormwater permits where the expectation is that load reductions will be achieved through application of BMPs.

For the Tillman, LA-Glendale, and Burbank POTWs, effluent monitoring requirements will be developed to ensure compliance with the daily and monthly limits for metals. Receiving water monitoring requirements in the existing permits will not change as a result of this TMDL.

The MS4 and Caltrans stormwater NPDES permittees are jointly responsible for the compliance assessment monitoring for the stormwater waste load allocations. Initially, there will be a single compliance assessment point for stormwater at the Wardlow gage station. This site is regularly sampled and maintained by the LACDPW as part of their MS4 permit. However, the co-permittess shall increase the number of compliance monitoring locations to demonstrate compliance with the phased implementation schedule for this TMDL (Table 35), which requires compliance in prescribed percentages of the watershed over a 15-year period. The monitoring locations specified for the ambient monitoring program (Table 41) may be used as compliance assessment monitoring locations.

The MS4 and Caltrans stormwater NPDES permittees will be found to be in compliance with the TMDL if the in-stream pollutant concentration at the first downstream compliance assessment location is equal to or less than the corresponding concentration- or load-based waste load allocation. Alternatively, compliance with interim compliance targets may be assessed at the storm drain outlet based on the numeric target for the receiving water. For storm drains that discharge to other storm drains, the waste load allocation will be based on the waste load allocation for the ultimate receiving water for that storm drain system.

This TMDL expresses waste load allocations in terms of loads and concentrations. A review of available water quality data suggests that applicable CTR limits are being met most of the time during dry weather, with episodic exceedances. Due to the expense of obtaining accurate flow measurements, which are required for calculating loads, the MS4 and Caltrans stormwater NPDES permittees may demonstrate compliance with concentration-based waste load allocations during dry weather.

Analysis of randomly selected discrete samples is preferred over time-weighted composite samples, as composite samples may mask episodic exceedances. It is suggested that samples be taken concurrently at all stations on an hourly basis for a 24-hour period. For each sample event, a least four timed sample periods shall be randomly selected. Samples taken from all stations during these time periods will be analyzed for total metals, dissolved metals and hardness. If exceedances of the waste load allocation occur, samples from subsequent time periods also shall be sampled to quantify the duration of the exceedance. In addition, an investigation shall be conducted in an attempt to identify the source of the exceedance.

The MS4 and Caltrans stormwater NPDES permittees shall demonstrate compliance during wet weather based on flow-weighted composite samples taken throughout the duration of the storm event at each compliance assessment monitoring location. Samples shall be collected for six storm events per storm year[2] or all storm events per year, whichever is less. A storm event is defined as a day that rainfall occurs plus all consecutive days that flow is above base flow. Rainfall that occurs following a day of no rainfall, even if flow is still above base flow, is considered a separate storm event. Permittees must report sample results, total storm volume, and total inches of rainfall. Compliance will be based on the load capacity curves for the corresponding rainfall (Figures 11a-11d).

If the compliance assessment monitoring location exceeds the applicable waste load allocation, then the responsible jurisdictions and agencies within the sub-watershed shall be considered out of compliance. Enforcement of the waste load allocations will proceed in accordance with the schedule detailed in Table 35. The responsible jurisdictions and agencies shall conduct a detailed source investigation of the sub-watershed(s) contributing to the reach where the exceedances occur.

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[2] The storm year is defined as November 1st through October 31st.

8.3 Special Studies

Additional monitoring and special studies may be needed to evaluate the uncertainties and the assumptions made in development of this TMDL.

1. Flow measurements. Better information is needed to define flow in the mainstem of the Los Angeles River and the tributaries where there are no stream gages. The biggest uncertainties are associated with low-flow in some of the listed tributaries. Better information is also needed about contributions of storm drains during low flow.

2. Water quality measurements. Information on background water quality will help refine the targets. Specifically, studies should be developed to provide a better assessment of background hardness values in areas where the data is old (lower reaches of Los Angeles River) or non-existent (Tujunga, Verdugo Wash, Arroyo Seco). Studies on background concentrations of total suspended solids and organic carbon will help with the refinement of the use of partition coefficients to define metals translators.

3. Effects studies. Special studies may be warranted to evaluate the appropriateness of the targets. Los Angeles County Sanitation District and others are testing an approach to use the Biotic Ligand Model in the Los Angeles Region. Measurements of dissolved organic carbon, alkalinity, humic acid, and alkali/alkaline metals would support this effort.

4. Source studies. There is a need for better characterization of the loadings from natural sources to verify the assumptions that the loadings from natural sources for copper, lead and zinc are generally low. A study should also be developed to verify the assumption that selenium concentrations observed in the upper reaches of the Los Angeles River are from natural background sources.

5. Other special studies. Special studies should also be considered to refine some of the assumptions used in the modeling, specifically the relationship between total and dissolved metals in stormwater, the assumption that metals loadings are closely associated with suspended

sediments, the accuracy and robustness of the potency factors, and the uncertainties in the understanding sediment washoff and transport.

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Figure 1. Map of the Los Angeles River watershed and listed reaches.

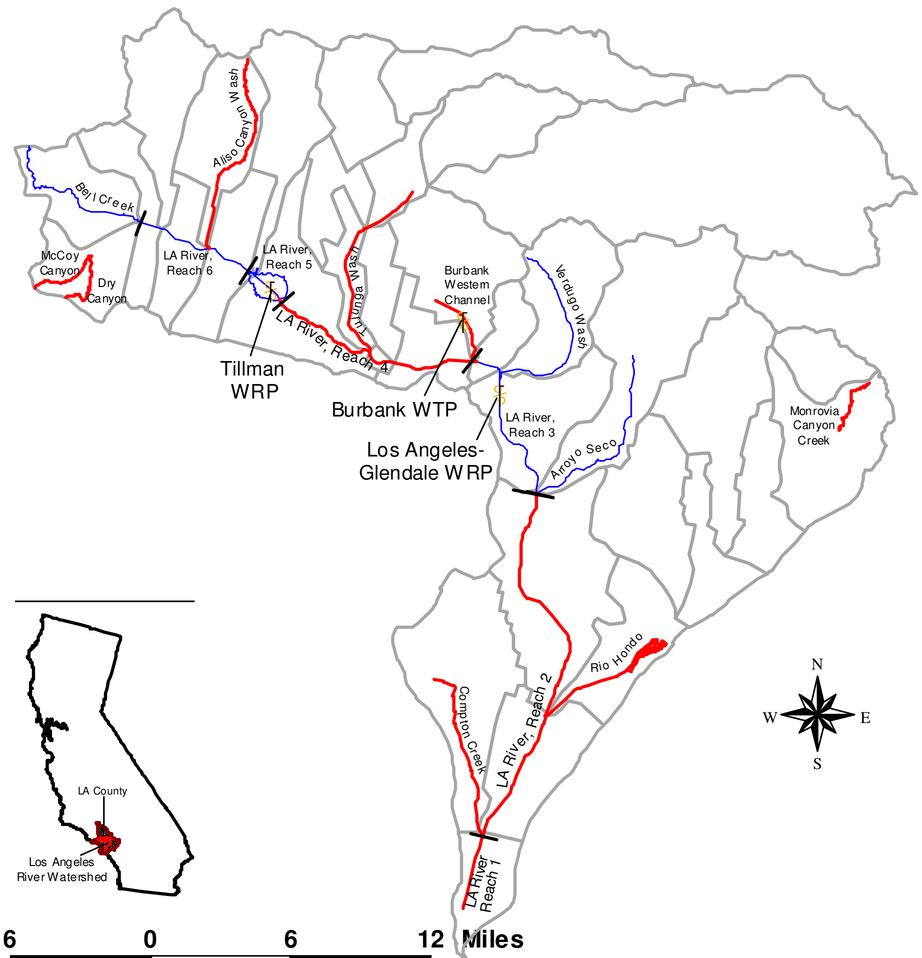


Figure 2. Sampling stations in the Los Angeles River watershed.

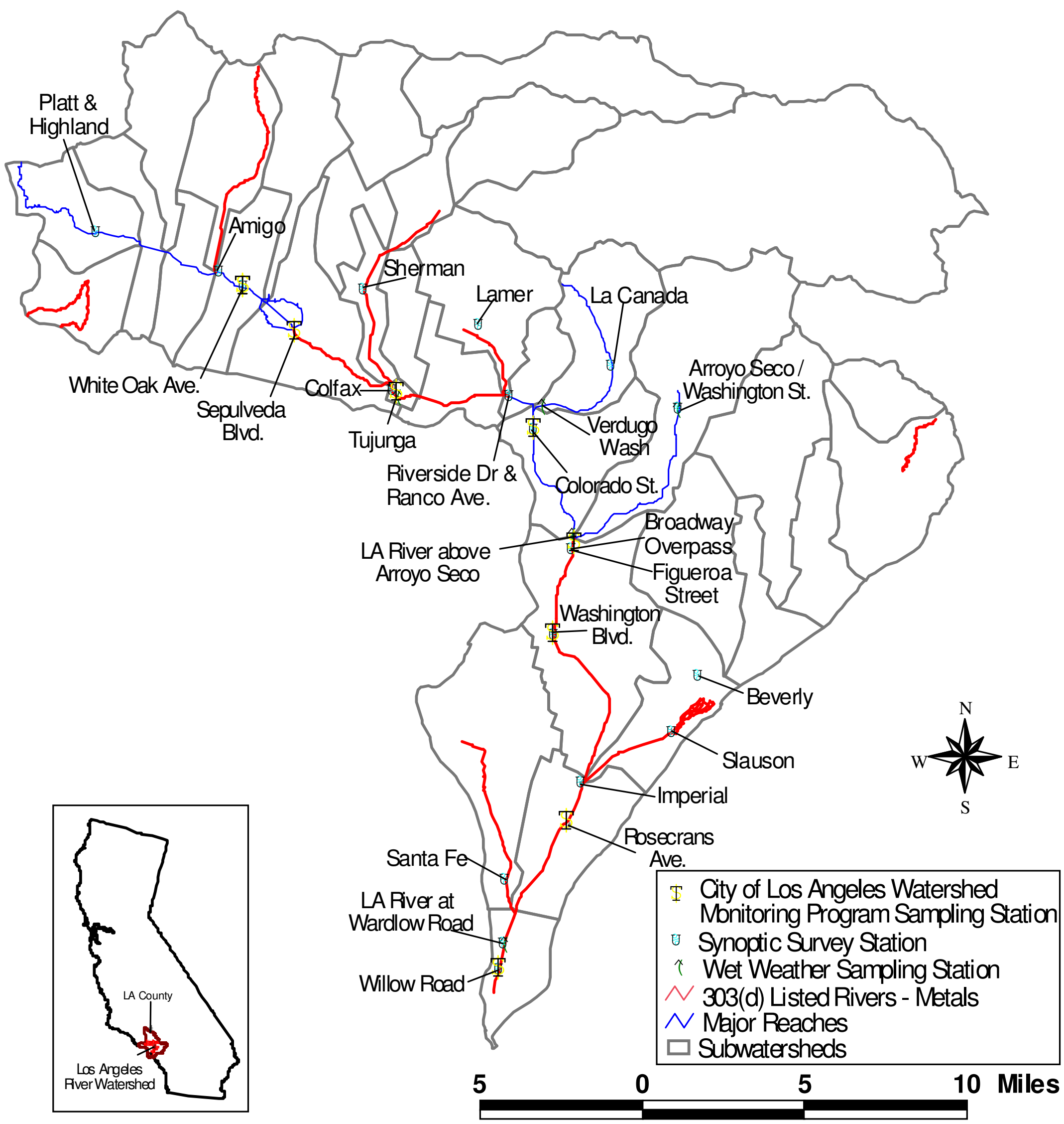
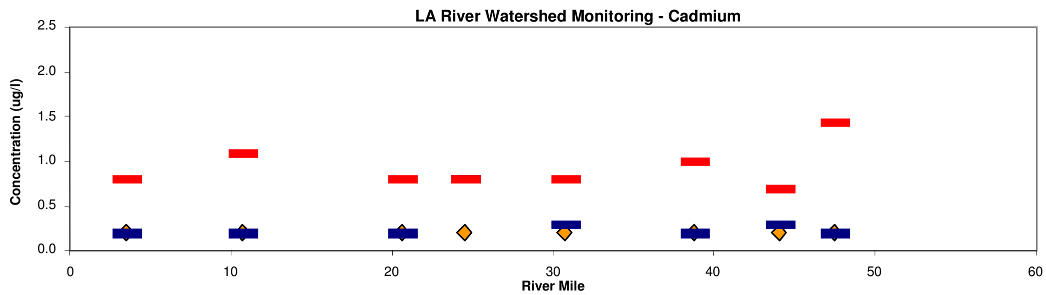


Figure 3. Data collected by the City of Los Angeles Watershed Monitoring Program.

3a.



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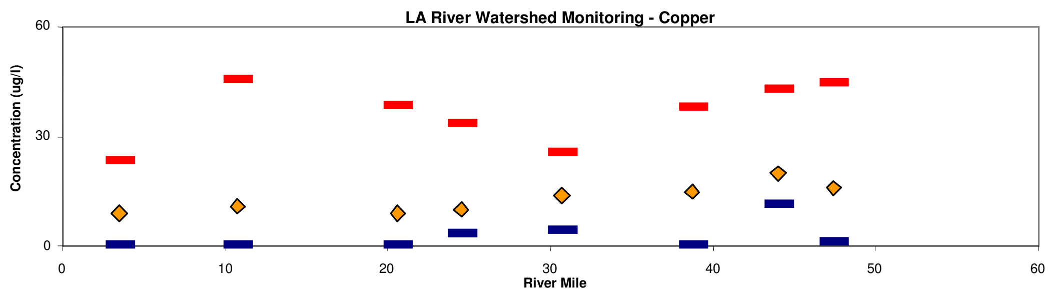

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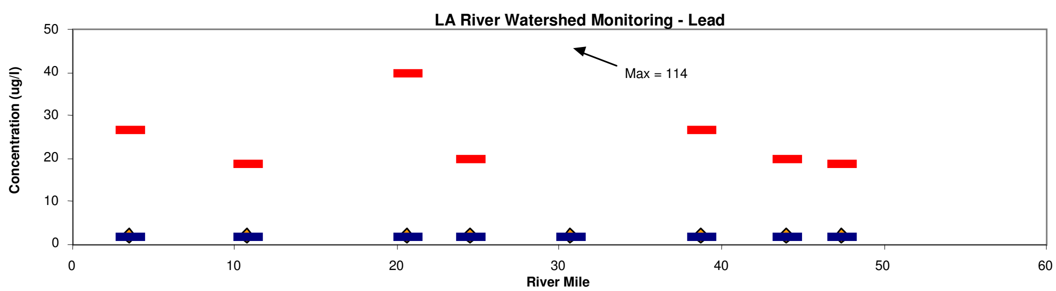

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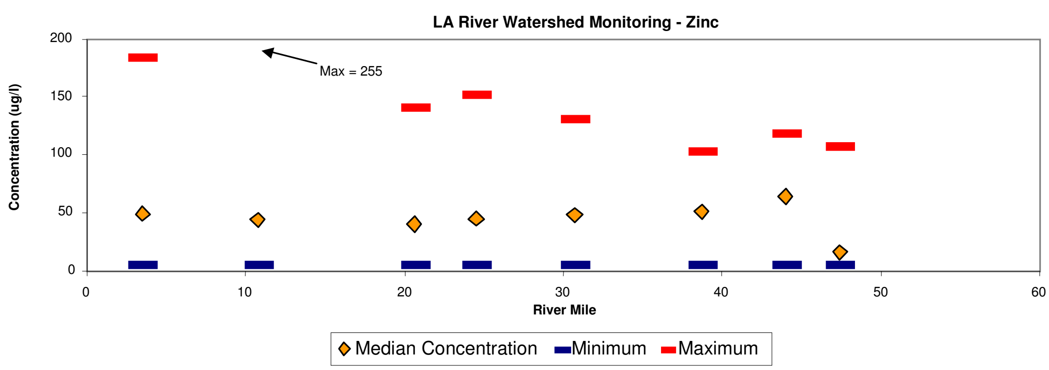


Figure 4. Location of stream gages in the Los Angeles River watershed.

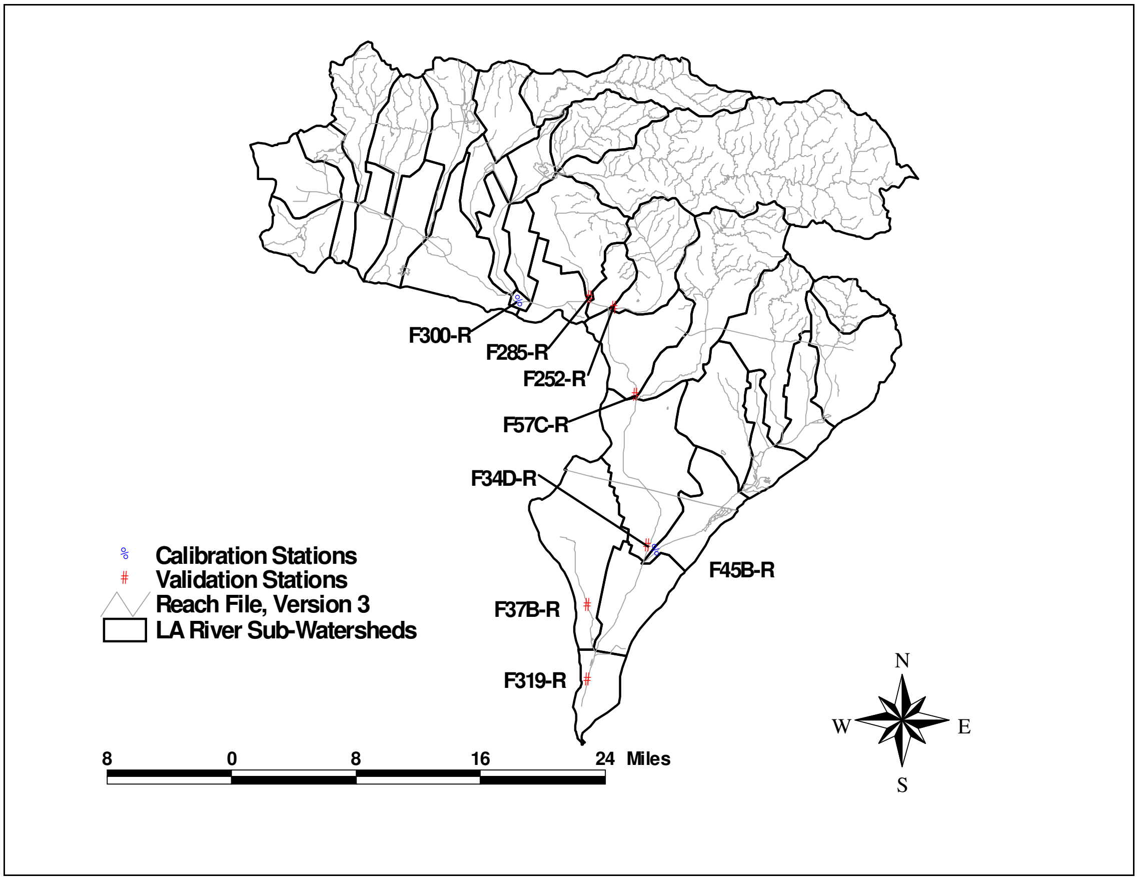


Figure 5. Validation of dry-weather hydrography.

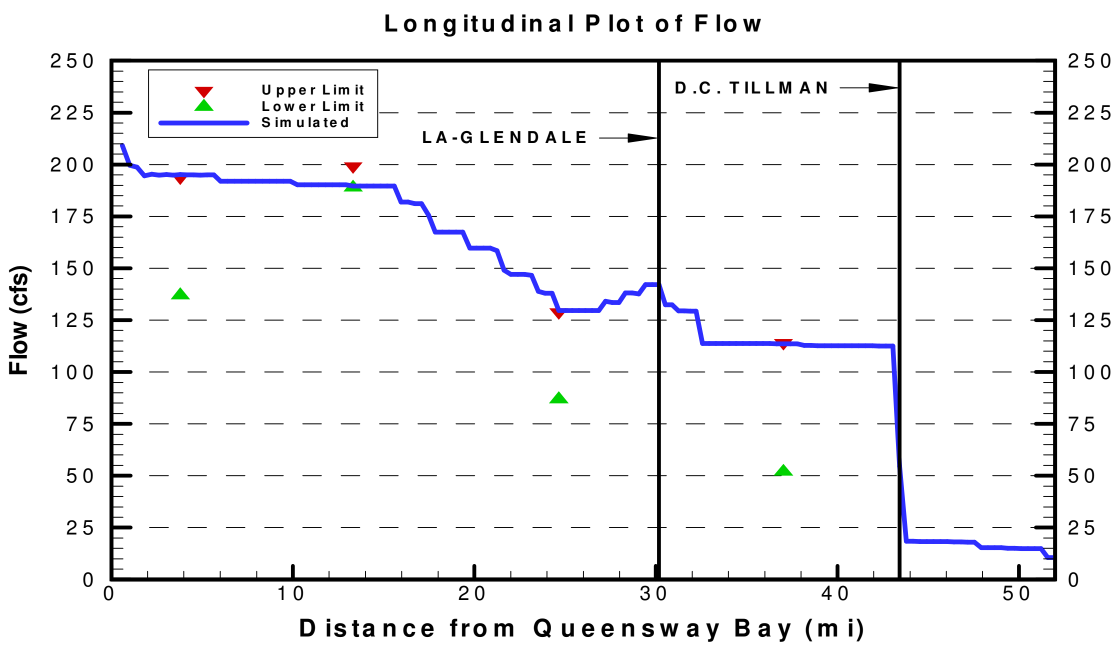
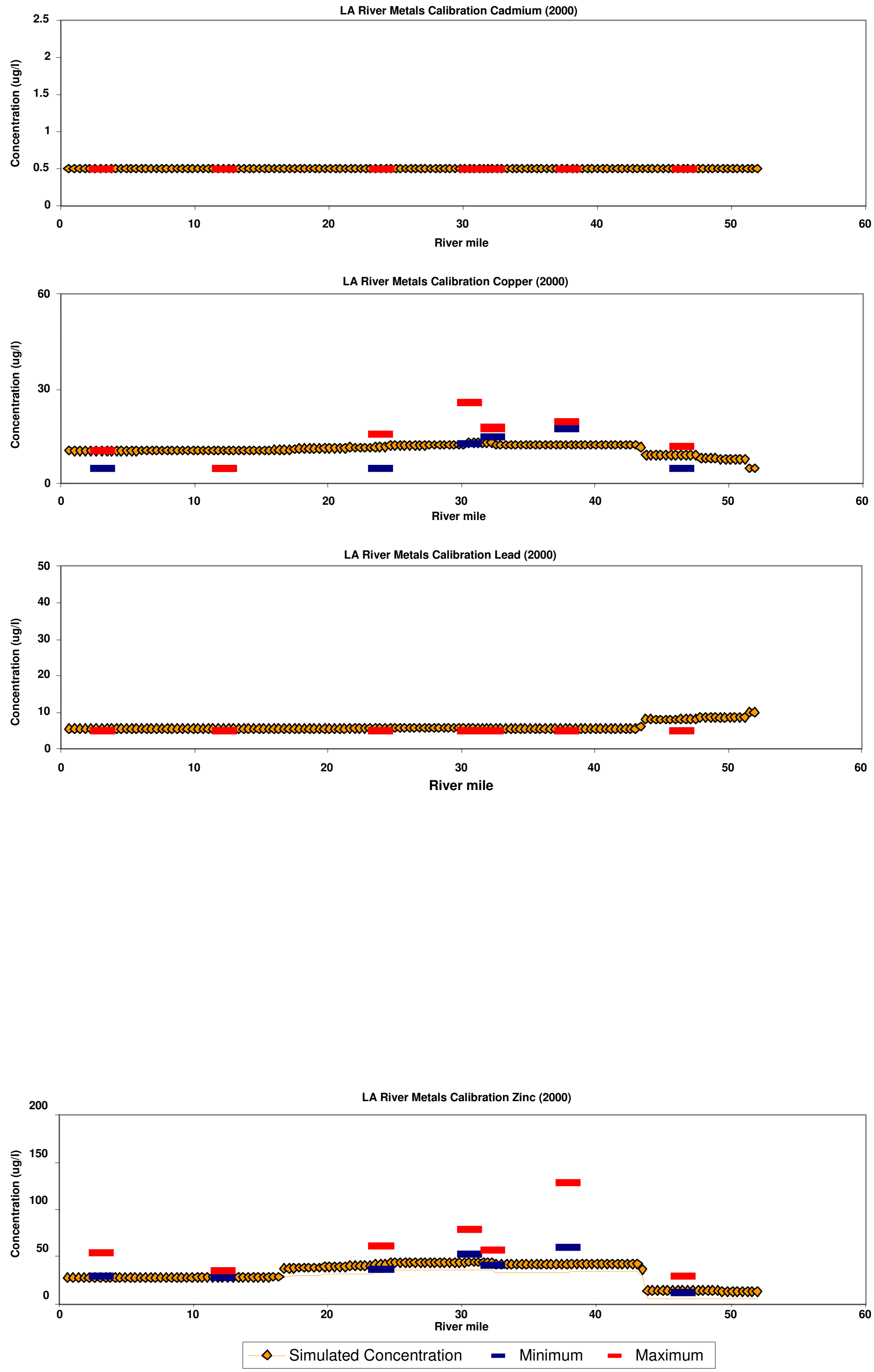
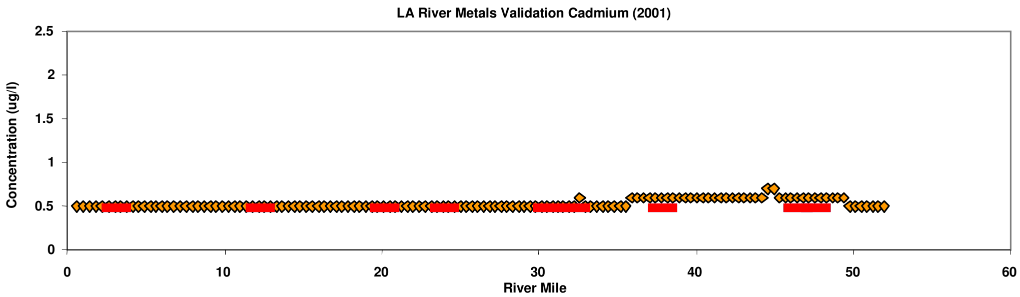
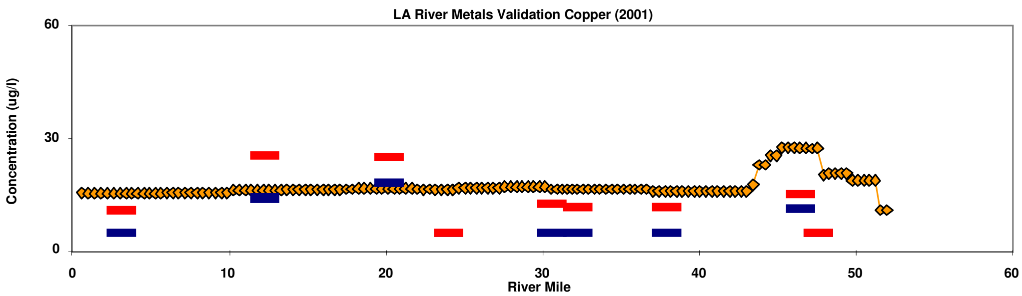
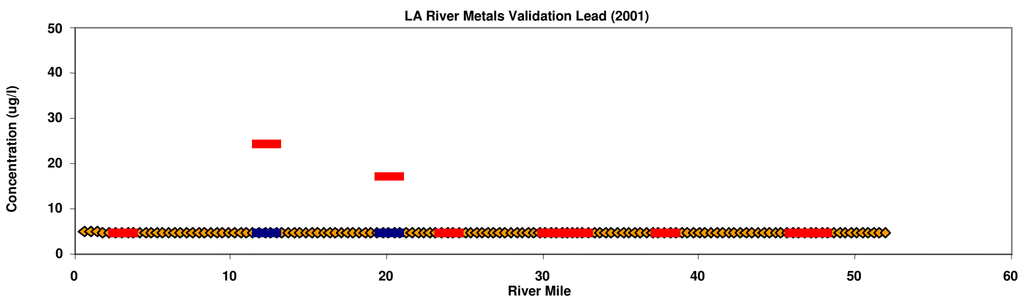


Figure 6. Calibration and validation of the Dry-weather model.




LA River Metals Validation Cadmium (2001)
Concentration (ug/l)
River Mile


LA River Metals Validation Copper (2001)
Concentration (ug/l)
River Mile


LA River Metals Validation Lead (2001)
Concentration (ug/l)
River Mile

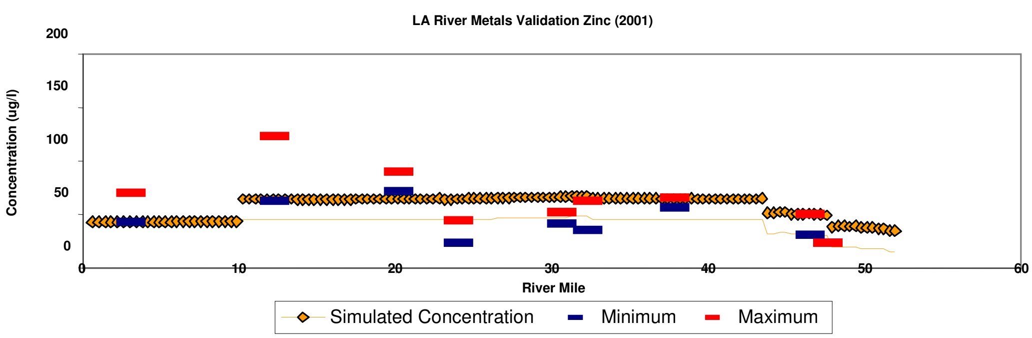

LA River Metals Validation Zinc (2001)
Concentration (ug/l)
River Mile
Simulated Concentration
Minimum
Maximum

Figure 7. Los Angeles River sub-watershed delineation used in wet-weather model.

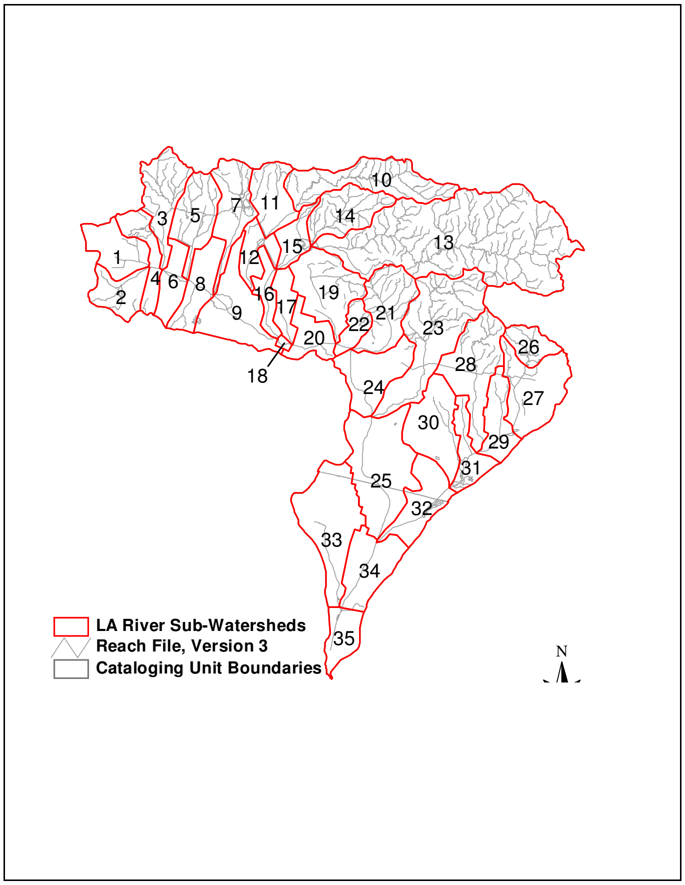


Figure 8. Location of precipitation and meteorological stations used in wet-weather model.

Figure 9a. Validation of wet-weather hydrography. Comparison of monthly flows.

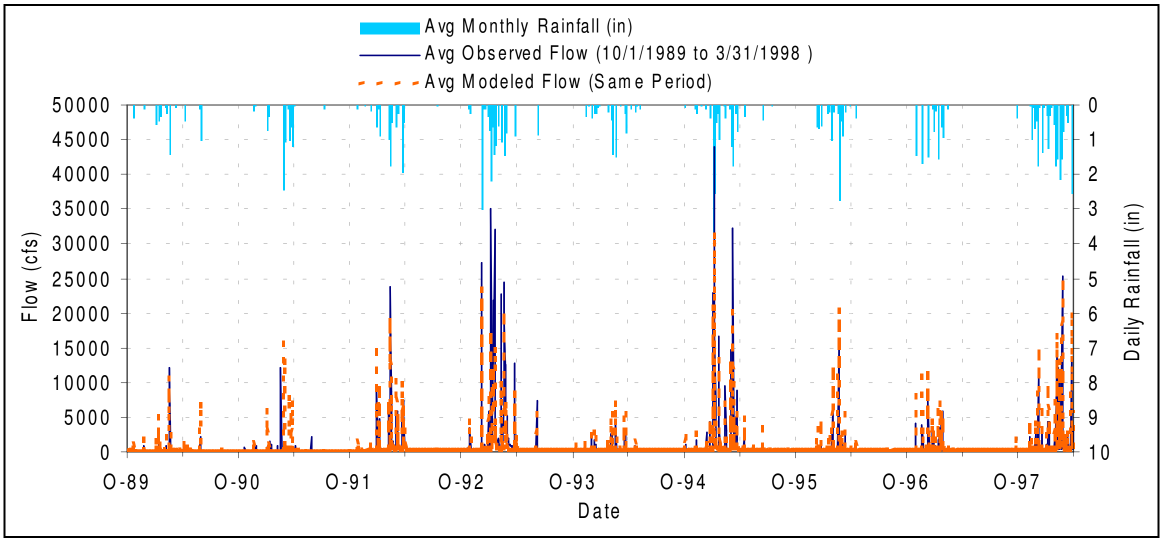


Figure 9b. Validation of wet-weather hydrography. Regression of monthly flows.

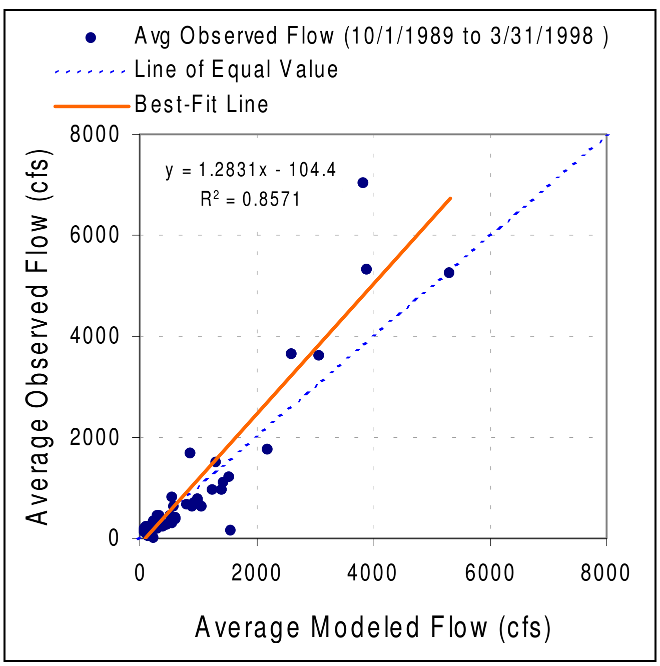


Figure 10. Flows at Wardlow (1998-2000)

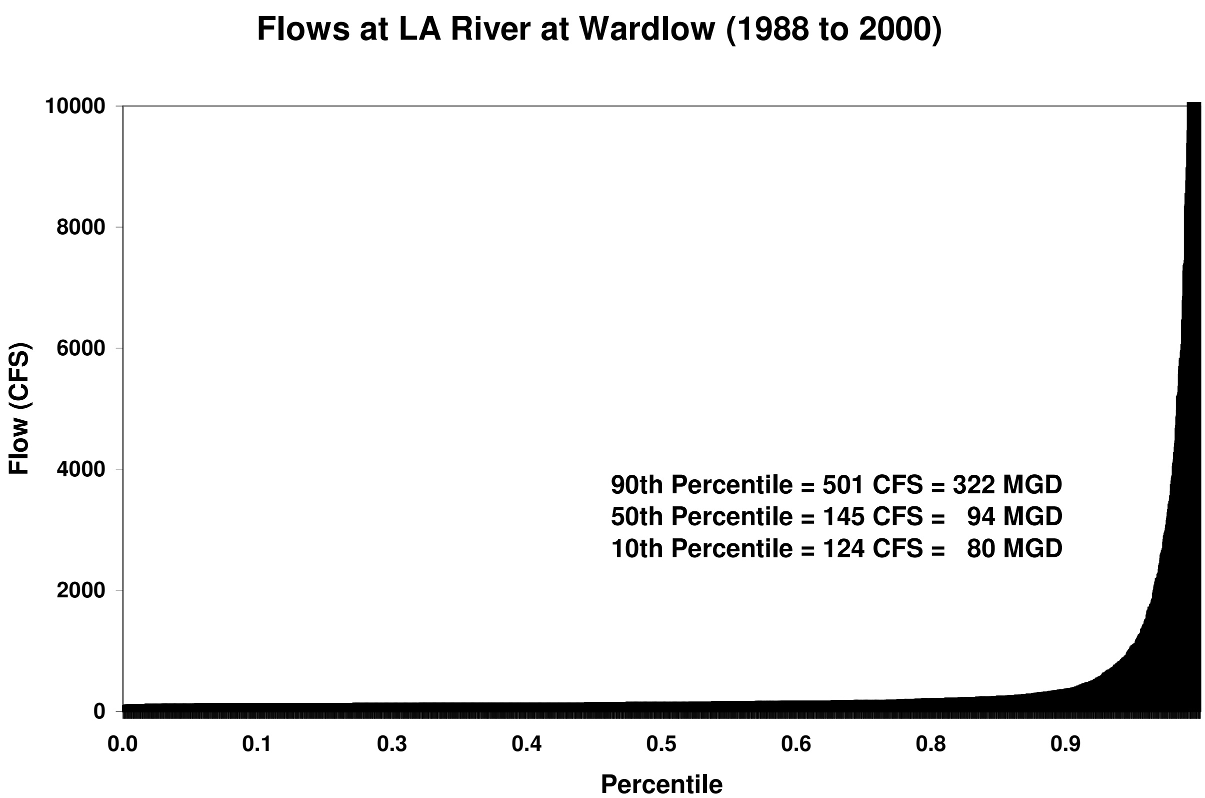
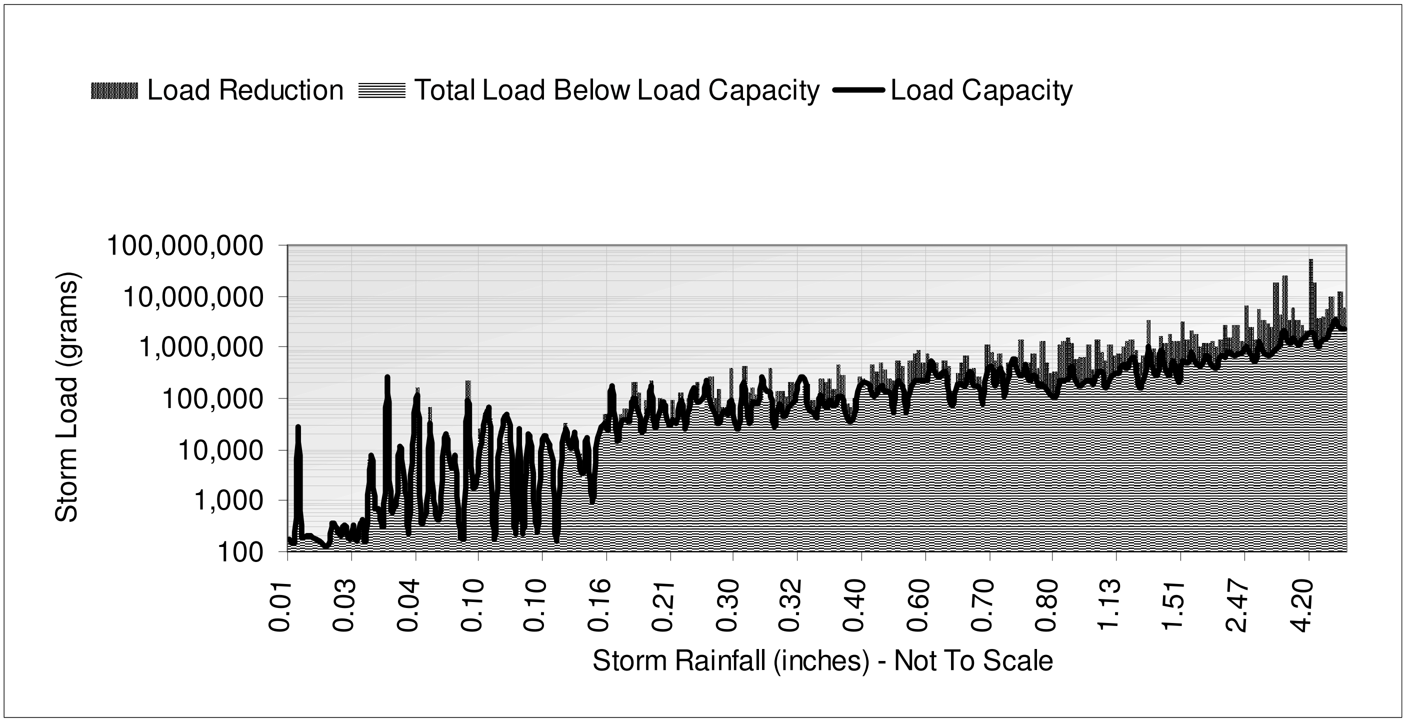


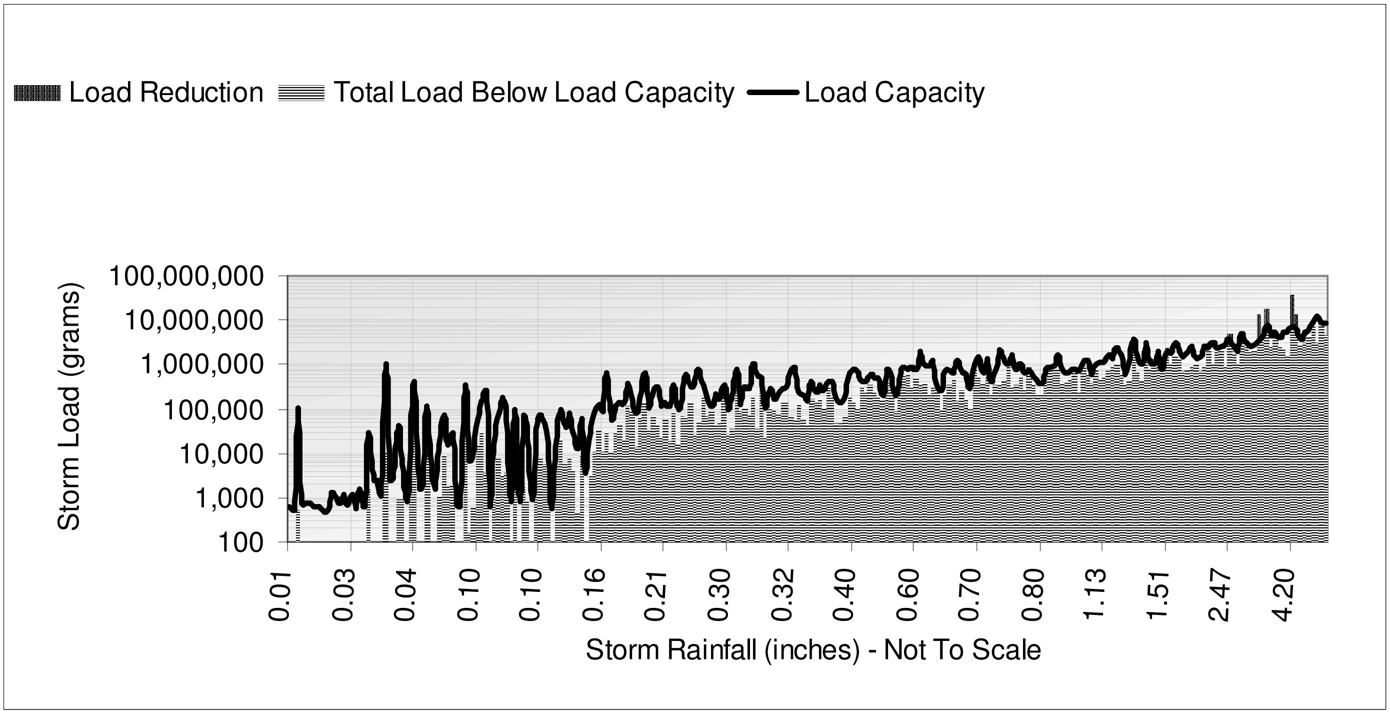
Figure 11a. Load-duration curve for copper



Computed Load Indicators:	Value	Units
Total Storms Over 12-Year Period	249	none
Total Below Load Capacity Curve:	70,590	kg
Total Existing Load (dots and dashes)	297,889	kg
Existing Load Below Load Capacity Curve (dashes):	69,706	kg
Existing Load Above Load Capacity Curve (dots):	228,183	kg
Estimated Load Reduction*:	76.6%	none

* Model predictions tend to overestimate loadings. Actual reductions required to meet the waste load allocations as defined by the load capacity curve may be less.

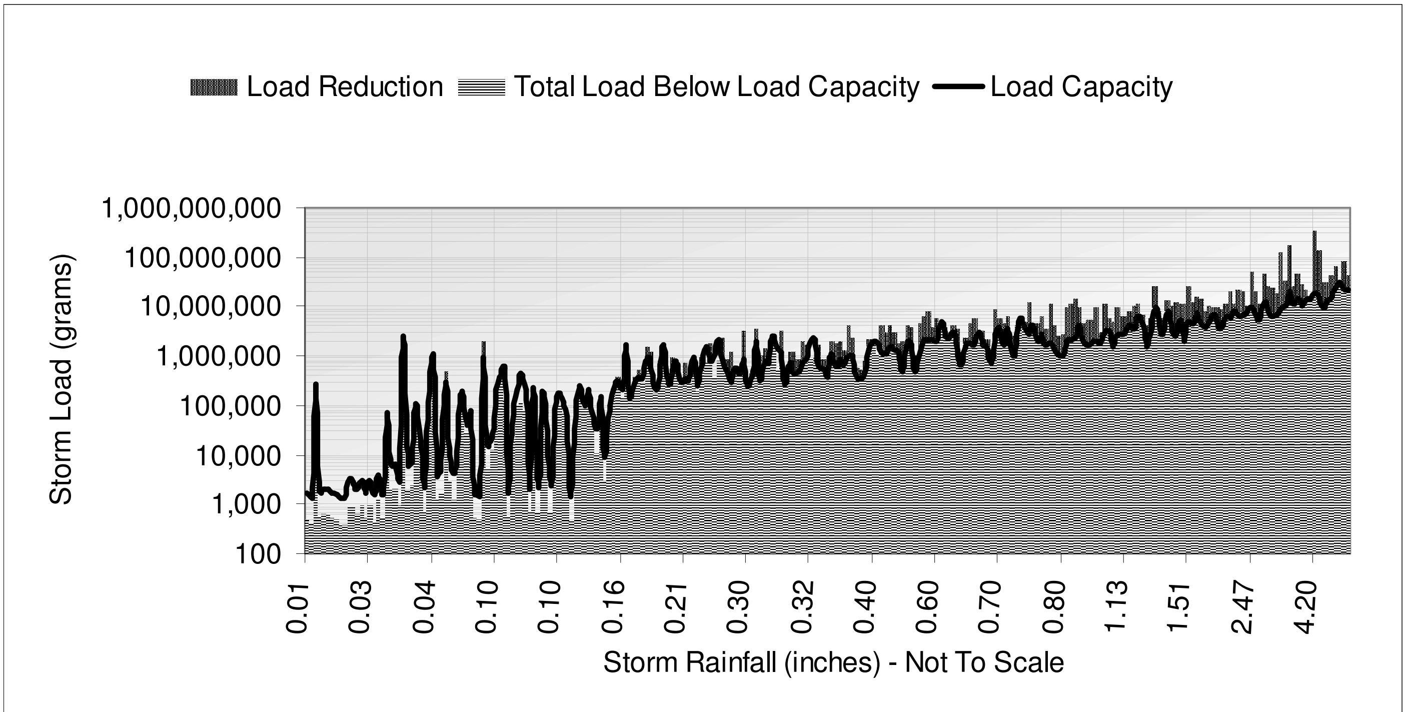
Figure 11b. Load-duration curve for <u>lead</u>



Computed Load Indicators:	Value	Units
Total Storms Over 12-Year Period	249	none
Total Below Load Capacity Curve:	259,431	kg
Total Existing Load (dots and dashes)	211,484	kg
Existing Load Below Load Capacity Curve (dashes):	153,686	kg
Existing Load Above Load Capacity Curve (dots):	57,797	kg
Estimated Load Reduction*:	27.3%	none

* Model predictions tend to overestimate loadings. Actual reductions required to meet the waste load allocations as defined by the load capacity curve may be less.

Figure 11c. Load-duration curve for <u>zinc</u>



Computed Load Indicators:	Value	Units
Total Storms Over 12-Year Period	249	none
Total Below Load Capacity Curve:	663,296	kg
Total Existing Load (dots and dashes)	2,208,313	kg
Existing Load Below Load Capacity Curve (dashes):	643,105	kg
Existing Load Above Load Capacity Curve (dots):	1,565,209	kg
Estimated Load Reduction*:	70.9%	none

* Model predictions tend to overestimate loadings. Actual reductions required to meet the waste load allocations as defined by the load capacity curve may be less.

Figure 11d. Load-duration curve for <u>cadmium</u>

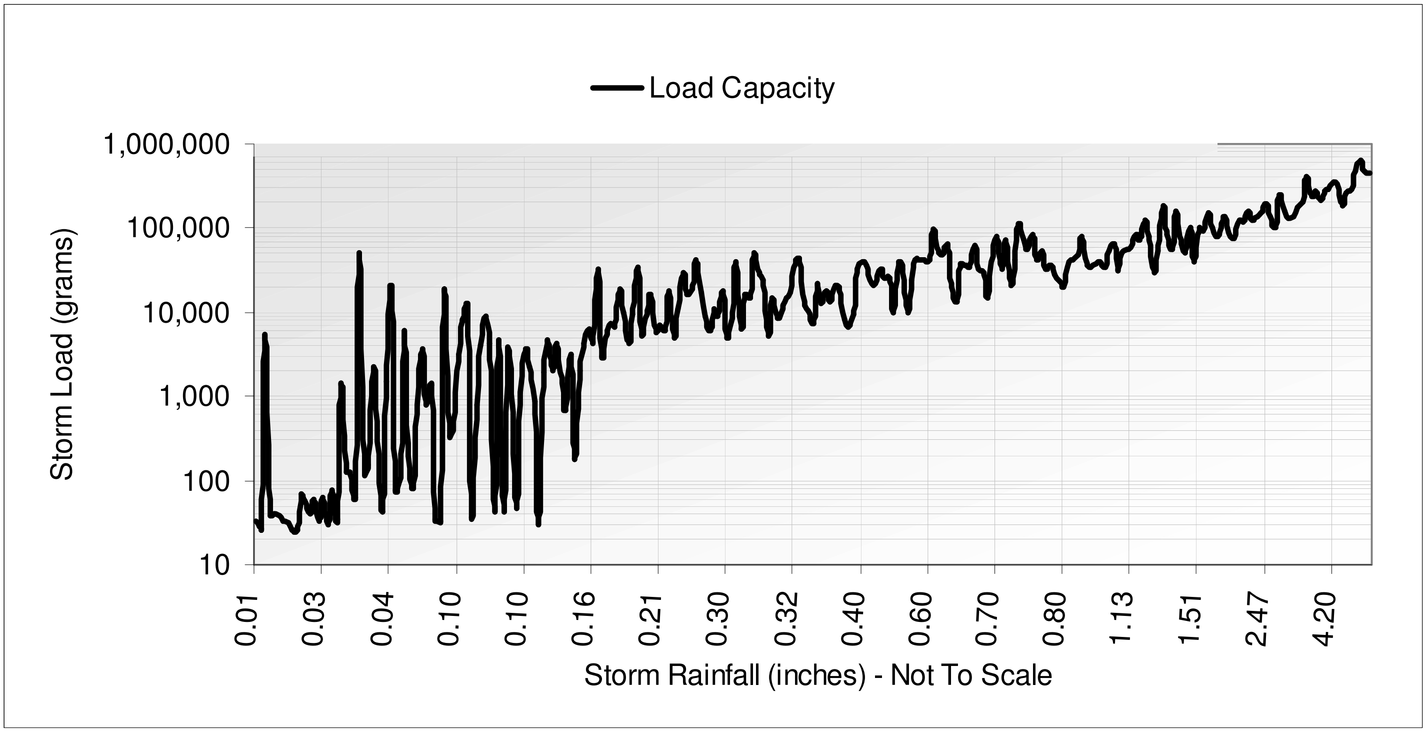


Figure 12. Regression analysis of storm flows verses rainfall for the Los Angeles River (below Wardlow)